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Geology and Mineral Resources of the Lakeview Mining District, Idaho

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156

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TABLE OF CONTENTS

	Page
ABSTRACT	I
INTRODUCTION	3
History of the Mining District	3
Previous Studies	5
Methods of Investigation	6
Acknowledgements	6
GEOLOGIC HISTORY	7
STRATIGRAPHY	9
Belt Supergroup	9
Ravalli Group	10
Wallace Formation	10
Lower Member	11
Middle Member	11
Upper Member	11
Cambrian Rocks	12
Gold Creek Quartzite	12
Rennie Shale	13
Lakeview Limestone	13
Metamorphism and Rock Alteration	13
Surficial Deposits	14
Glacial Deposits	14
Post-glacial Deposits	15

	Page
INTRUSIVE ROCKS	17
Granodiorite	17
Mafic Dikes	18
Age	18
STRUCTURE	21
Faults	21
Packsaddle Fault	21
Other Faults	22
Shear Zones	23
Thrust Fault	24
Joints	24
Structural Interpretation	24
MINERAL DEPOSITS.	27
General Characteristics	27
Mineralogy	27
First Stage Minerals.	28
Arsenopyrite	28
Early Quartz	28
Early Pyrite	28
Rhodochrosite and Siderite.	29
Sphalerite	29
Galena	29
Tetrahedrite	30
Second Stage Minerals	30
Supergene Minerals	31
Paragenesis	31
Description of the Mines	33

	Page
Conjecture Mine	33
Weber Open-Pit and Mine	36
Idaho Lakeview Mine	36
Keep Cool Mine	38
The Glasscock Properties	38
Other Mines	40
CONCLUSIONS	43
REFERENCES	45

LIST OF ILLUSTRATIONS

PLATES

- Plate 1. Geology of the Lakeview Mining District, Idaho
- Plate 2. Cross Sections from Plate 1
- Plate 3. Geologic and Composite Mine Maps Idaho Lakeview Mine
- Plate 4. Geologic and Composite Mine Maps, Conjecture Mine Area
- Plate 5. Section A-A', Conjecture Mine Area
- Plate 6. Geologic, Composite Mine and Cross Section Maps, Weber Mine

FIGURES

- Fig. 1. Location Map, Lakeview Mining District
- Fig. 2. Generalized Geologic Map, Lakeview Area
- Fig. 3. Stratigraphic Section, Lakeview Quadrangle
- Fig. 4. Granodiorite Hand Specimen, Showing Porphyritic Texture
- Fig. 5. Granodiorite Thin Section of Specimen from Fig. 4
- Fig. 6. Lamprophyre Thin Section from Outcrop in Weber Pit
- Fig. 7. Schematic Diagram of Some Shear Zones
- Fig. 8. Combined Geologic and Total Aeromagnetic Intensity Map.
- Fig. 9. Polished Section of Ore from Conjecture Mine
- Fig. 10. Arsenopyrite Partially Replacing Siltite and Being Replaced by Early Quartz, Conjecture Mine
- Fig. 11. Breccia of Early Quartz Partially Replaced by Galena and Tetrahedrite, Vulcan Mine
- Fig. 12. Polished Surface Typical High Grade Ore, Conjecture Mine
- Fig. 13. Polished Surface Showing Replacement and Fracture Filling in Quartz, Keep Cool Mine
- Fig. 14. Micrographic Intergrowth of Galena and Tetrahedrite, Conjecture Mine.
- Fig. 15. Crustification of Galena and Quartz in Typical Fracture Filling Texture, Conjecture Mine

- Fig. 16. General Mineral Paragenesis, Lakeview District
- Fig. 17. Mineral Paragenesis, Conjecture Mine
- Fig. 18. Mineral Paragenesis, Weber Open Pit Mine
- Fig. 19. Mineral Paragenesis, Idaho Lakeview Mine
- Fig. 20. Plan and Cross Section Maps, Keep Cool Mine
- Fig. 21. Mineral Paragenesis, Keep Cool Mine
- Fig. 22. Mineral Paragenesis, Vulcan Mine and Glasscock Adits

GEOLOGY AND MINERAL RESOURCES OF THE LAKEVIEW MINING DISTRICT, IDAHO

by

Peter Kun

ABSTRACT

The Lakeview district is situated about thirty miles north of the Coeur d'Alene mining district, on the southeastern shore of Lake Pend Oreille. The area is underlain by sedimentary and metasedimentary rocks of the Precambrian Belt Supergroup and by Cambrian quartzites and limestones. Glacial deposits occupy most valleys, and in places these are buried by younger alluvium and mass gravity deposits.

The Precambrian and Cambrian rocks are cut by a Cretaceous (?) granodiorite stock and by lamprophyre dikes, believed to be related to the Kaniksu Batholith. The intrusion, with an estimated K/A age of 99 ± 10 million years, was followed by several metamorphic events which could be as recent as 11 million years. Slight regional metamorphism has affected the sediments on the southeastern portion of the quadrangle. High-grade thermal metamorphism is present around the granodiorite stock. Hydrothermally altered rocks occur around the veins and shear zones. The alteration is manifested by chloritization and sericitization of the surrounding bedrock, as well as the occurrence of disseminated pyrite cubes.

The northeast-trending Packsaddle fault, which bisects the mapped area and is the principal structural feature, is a steep, west-dipping normal fault with 1,000 ft. horizontal displacement and a throw of about 7,000 ft. South of the Packsaddle fault, fractures are north-trending faults and east-trending faults and shear zones. The north-trending faults show recurrent movement, are surrounded by hydrothermally altered zones, and are probably associated with the Packsaddle fault. The east-trending faults and shear zones, with a maximum estimated throw of 800 ft., contain the sulfide orebodies which have been mined. North of the Packsaddle fault, some fractures are filled by quartz and metallic sulfide veins. Faulting is intense in this area because of the shallow nature of the underlying stock. The area is thus divided in small fault blocks.

Four major and several minor mines produced an estimated \$2,000,000 in silver, lead, zinc, and silica. The known orebodies have been found at structural intersections rather than on stratigraphic horizons, as is the case in most mines of the Coeur d'Alene mining district. The orebodies are located within shear zones, close to intersections with north-trending, barren faults. The orebodies occur as high-grade shoots, formed chiefly by fracture filling and sometimes by replacement of older minerals or bedrock. The ore shoots are bounded by shear zones. Two hypogene and one supergene stage of mineralization can be recognized in the district. During the first hypogene stage, arsenopyrite, early quartz, early pyrite, rhodochrosite, siderite, sphalerite, galena, and tetrahedrite were deposited.

The second hypogene stage is characterized mainly by the deposition of large masses of clear, barren quartz. The supergene stage, during which cerussite, angleite and secondary silver-bearing minerals were deposited, was of economic importance because most of the previous mining was restricted to the upper portions of the orebodies.

Several outcrops of previously unreported oxidized veins were found during this study. These veins and the deeper extensions of the ore shoots previously mined, give the Lakeview area a mineral potential of immediate economic interest.

INTRODUCTION

The Lakeview mining district, Bonner County, is in the Idaho panhandle, on the southeastern tip of Lake Pend Oreille (Fig. 1). Lakeview is about 35 miles northwest of the Coeur d'Alene mining district and 30 miles north of the city of Coeur d'Alene, and 60 miles south of the Canadian-United States border.

The town of Lakeview had a population of 5,000 in 1888, and a steamer service connected Sandpoint, Bayview, and Lakeview (Fig. 1). Lakeview is now only a summer resort. It can be reached from U.S. 95 by good dirt roads which are kept open between June and October by the U.S. Forest Service, and from Bayview a launch carries mail, supplies, and passengers to Lakeview throughout the year.

The area has short, hot and dry summers, moderately wet springs and autumns, and relatively mild winters with heavy localized snowfall. The temperature varies from about 80° in the summer to -20° in the winter, in the vicinity of the Conjecture Mine. The temperature limits are more extreme at higher elevations, but in Lakeview the temperature rarely falls below freezing. Snow was found in places at higher elevations until mid-June, 1967, and a heavy snowfall was observed in mid-October of the same year.

Most of the area is within the Kaniksu and Coeur d'Alene National Forests. Dense forests of conifers and thick brush cover most of the northern slopes and valley floors. Secondary growth of conifers, replacing forests destroyed by fire and areas that have been logged, are abundant in the northern part of the mapped area.

Altitudes of the mapped area range from 2063 feet at lake level, to 5146 feet on Green Mountain (northern part of the quadrangle, Pl. 1). Most slopes are steep with an estimated average gradient of 30 degrees, but varying from 10 degrees and less on the tops of ridges to over 60 degrees on the lakeshore cliffs. The drainage consists of deeply entrenched streams, some of which show marked control by joints and faults.

History of the Mining District

William A.D. Bell, Peter Steinmetz, and Albert Chamberlain were about to return empty-handed to Eagle City, Idaho, after a long summer of prospecting in northern Idaho, when they decided to check a prominent outcrop visible to the north from what, today, is called the Pend Oreille divide (at the junction of Bunco and Weber roads, SE $\frac{1}{4}$, sec. 35, T. 53 N., R. 1 W.). The samples from this outcrop showed massive sulfides (and later produced assays as high as 200 oz/ton in silver). The prospectors, between September 27, and October 8, 1888, located eleven claims in the names of A. Weber and S.P. Donnelly, the men who had financed their prospecting. The prominent gossan outcrop was located near the headwaters of Gold Creek (then called East Chloride Gulch), on what is now the Weber Pit (anonymous, unpublished private report, 1925).

The news of the discovery of the new district in 1888 produced an exodus from Wallace, Burke, Murray, and Eagle cities in the Coeur d'Alene mining district, the three last-mentioned towns being nearly emptied. By the winter of 1888-89, the new town of Chloride (SE $\frac{1}{4}$, sec. 15, T. 53 N., R. 1 W) had a population of 2,000 people, "but after several months of riotous living, most of them left the district,..." (Sampson, 1928). The Smith ranch now marks the former site of Chloride.

The first carload of 40 tons of ore was shipped to Great Falls, Montana, in January, 1889, and averaged 47 oz/ton in silver and \$1.80 in gold. Later ore shipments were made to the Molton Mill, Butte, Montana, until 1895 when a 30-ton capacity stamp mill was built in Lakeview. The mill proved to be a failure because the silver and gold were floated off with the antimony and lead, yielding only 33 percent of the total precious metal content (private report, 1925). In 1896, a forest fire destroyed all the building and timbering, and thereafter ore from the Weber Mine was shipped to Tacoma, Washington, for processing.

During the period from 1889 to 1917, the Keep Cool, Idaho Lakeview, and several adits and small shafts in the Conjecture Mine area, were located. A smelter was built in the late 1880's at Sandpoint, Idaho, and ore from the entire Pend Oreille mining district was shipped there by lake steamers. It proved to be an economic failure and closed shortly afterwards.

In 1906, Frank Weber sold a three-quarter interest in the Weber Mine to the Standard Development Co. of Chicago, but the contract was never completed, and litigation followed until 1920. The mine reopened in 1921, and the main level (no. 4 on Pl. 6) was developed and enlarged prior to 1925 (anonymous, unpublished private report, 1925).

By 1923, in the present-day Conjecture Mine area, the Spider and Graham adits had been driven. A systematic exploration program in this area by T.C. Cunningham of the Lakeview Silver Mines Company led to the discovery of a large ore-body (Sampson, 1928). Workings included the Spider adit, 1150 ft. long, the Graham adit, 600 ft. long, and a 200 ft. inclined shaft (Campbell, 1923).

In the same year, 1923, the Venezuela Mine (now the Idaho Lakeview Mine) had only a 900 ft. long adit and employed two people. In 1924, the mine and adjacent claims were taken over by the Hewer Mining Company which started an intensive underground exploration program and built a mill which operated for some time (Campbell, 1924). This activity continued for several years and included the sinking of an inclined shaft (Pl. 3), which exposed two new ore bodies (Campbell, 1926).

During the mid-1920's, the International Portland Cement Co. mined large quantities of Lakeview Limestone from mines in the vicinity of Bayview and Lakeview (Fig. 1), and was the largest producer of cement in Idaho during that time (Campbell, 1924 and 1926). All limestone was shipped to the company's plant near Spokane, Washington.

In later years, development continued mainly in the Keep Cool and Conjecture mines. In 1938, the Keep Cool Mine was milling its own ore and shipping the concentrates by truck to the Bunker Hill Smelter, at Bradley, Idaho. Drifts were driven along the vein at five levels with the lowest, no. 5, being the main haulage way. This adit was 530 ft. long and timbered at intervals (private report, 1938).

An editorial in the Mining and Machinery Journal (1938) states that:

"W.M. Cady, manager of the Silver Leaf mines near Lakeview in Bonner County, Idaho, says his company is planning enlargements of the mill to a capacity of 100 tons daily. 'There is lots of ore in the property' he said. A cross vein is being opened by drift."

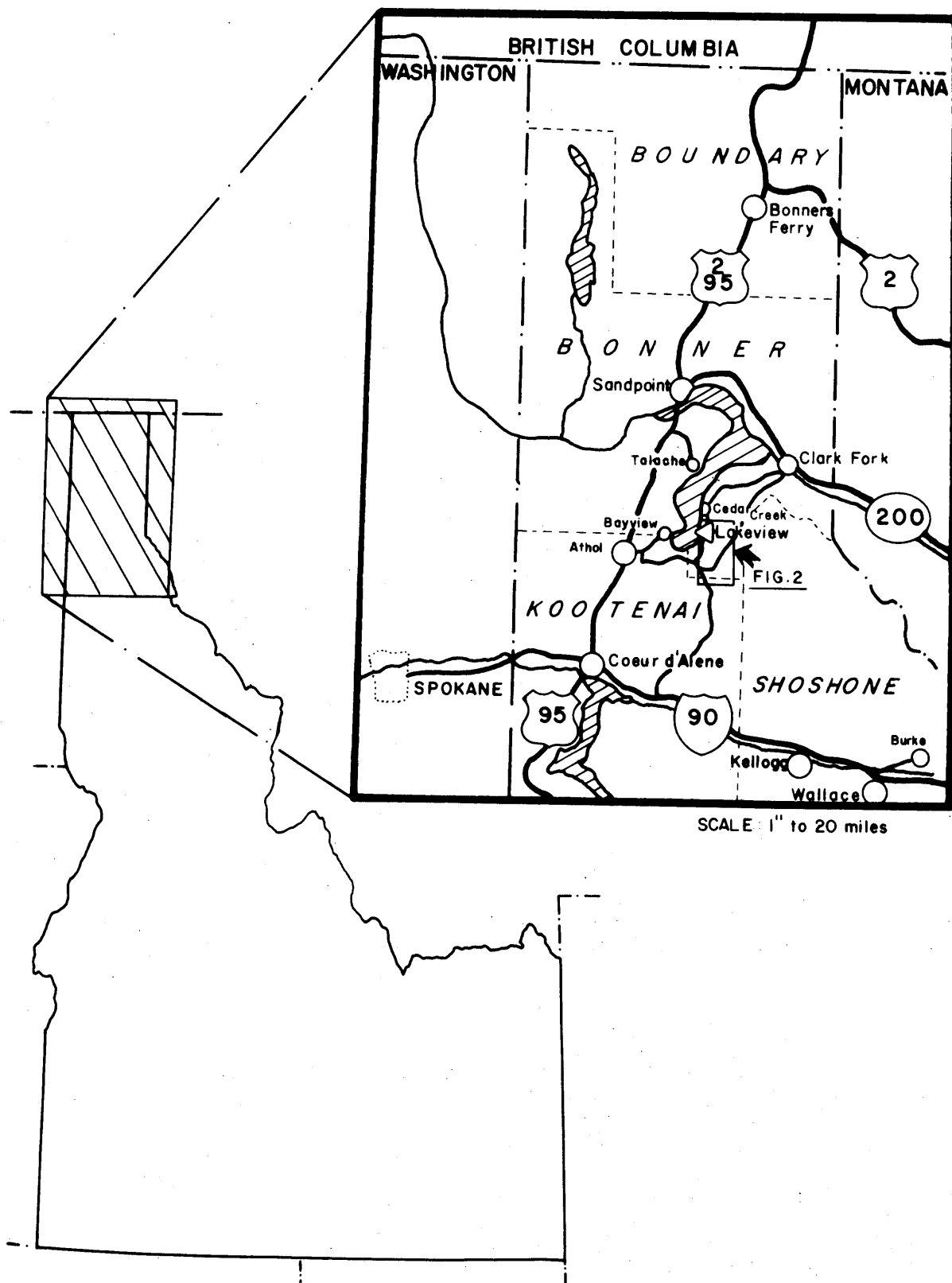


Figure 1. Location of the Lakeview mining district, Idaho.

In January, 1951, D.E. Majer and L.H. Funnell purchased the Conjecture Mine and adjacent properties, and formed Conjecture Mines Inc. In 1956, the existing inclined shaft was reopened and deepened from the 400 ft. level, where it had been extended earlier, to the 700 ft. level. About 3,000 ft. of workings uncovered two large ore shoots.

In late 1956, Federal Resources Corporation leased the Conjecture, Silver Leaf, Keep Cool, and Idaho Lakeview mines, and adjacent claims and initiated a detailed surface and underground exploration and assessment program of the properties. Trenches were dug between the Silver Leaf, Conjecture and Keep Cool mines (Pl. 1), and a new 2,000 foot deep, three-compartment shaft was sunk at a point about 600 ft. north of the Conjecture inclined shaft. About 12,000 ft. of drifts on four levels were driven and carefully mapped (Pl. 4 and 5). In 1964, Federal Resources ended their exploration work and returned the property to Conjecture Mines, Inc. The property was leased in 1967 by Duval Corporation, and surface exploration work was done during the same year and in the summers of 1968 and 1969, with partial dewatering of the vertical shaft. Some diamond drilling was also done with one hole being drilled in excess of 4,000 feet. The property was returned to Conjecture Mines, Inc. in 1970.

The Keep Cool Mine, which had produced ore until World War II, was partially reopened in the summer of 1967 for exploration work. The Keep Cool and Idaho Lakeview mines were leased in 1967 by Sunshine Mining Co. of Kellogg, Idaho. The Idaho Lakeview Mine reportedly operated as late as 1956 (Savage, 1967), but showed signs of having been idle for a long time when visited in 1967.

The Austin-Meyer Corporation leased the Weber Pit in 1949, and until recently has regularly shipped silver ore to the American Smelting and Refining Company smelter in Tacoma, Washington (private report, 1960).

The Vulcan Mine and surrounding adits, north of Lakeview ($S\frac{1}{2}$, sec. 35, T. 54 N., R. 1 W) have been intermittently worked by R. Glasscock during the 1950's and 1960's. The Vulcan Mine, which was caved at the portal in 1967, was reportedly reopened in 1968.

Previous Studies

Previous work in the area includes a geological reconnaissance report of northern Idaho by Calkins (1909), a guidebook of northern Idaho by Campbell and others (1915), and Sampson's (1928) comprehensive report on the Pend Oreille mining district. The latter made the first known reconnaissance map of the Pend Oreille mining district including the Lakeview Talache and Falls Creek-Granite Creek mines. Sampson also presented the first paragenetic study of the ore minerals of the district, and discussed the relationships of the veins to the geologic structures. The first report on the plutonic rocks of the Pend Oreille Lake area was published by Gillson in 1927. The same author (Gillson, 1929) also studied the contact metamorphism in areas around the lake basin.

Since 1961, members of the U.S. Geological Survey have been investigating the area to the north of Lakeview. Harrison and others (1961) published a study of the structures of the Clark Fork area (on the northeast part of Pend Oreille Lake). This report was followed in 1963 by a bulletin on the geology of the Clark Fork quadrangle by Harrison and Jobin, a study of Belt Stratigraphy (Harrison and Campbell, 1963), and a geologic map of the Packsaddle Mountain quadrangle (Harrison and Jobin, 1965), which is

located adjacent to and north of the Lakeview quadrangle.

Savage (1962) made a brief study of an aeromagnetic survey of eastern Bonner County in 1967. Griggs (1968) made a geological reconnaissance of the area north of the Coeur d'Alene mining district which includes the Lakeview quadrangle. Various other studies and maps of the mining properties in the Lakeview mining district are unpublished.

Methods of Investigation

The mapping for this report was done during the summer of 1967, using air photos from the U.S. Forest Service. Field information was compiled on vertical air photos at a scale of 1:15,840. The information was then transferred to enlargements on a scale of 1:12,000 and to the topographic map of the Lakeview quadrangle at the same scale. Laboratory work consisted of the study of petrographic sections of representative rock samples of the district, study of polished ore samples, and analysis by atomic absorption of selected rock samples.

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GEOLOGIC HISTORY

The known geologic history of northern Idaho starts in Late Proterozoic time with the deposition of several tens of thousands of feet of sediments in the Belt geosyncline. Fine-grained sand, silt, clay, and carbonaceous sediments derived from gneisses and schists of Archean (pre-Belt) age accumulated as shallow-water deposits in this geosyncline (Ross and others, 1963). The lower Belt Supergroup rests on metamorphic basement rocks dated by the K/Ar method at 1800 m.y. $\pm$ 100 m.y. (Obradovich and Peterman, 1968) and by the zircon Pb/Pb method at 2500 m.y. (Reid, oral communication, 1969). Purcell Sills, which intrude the lower Belt in northern Idaho and British Columbia, have been dated at 1075 to 1110 m.y. (Obradovich and Peterman, 1968). Their emplacement probably coincided with the first metamorphism of the Belt Supergroup. The age of the upper Belt Supergroup is considerably younger. The Garnet Range Formation (Upper Missoula Group) in northwestern Montana provides a minimum K/Ar age of 760 m.y. (Obradovich and Peterman, 1968) for the Belt Supergroup. An unconformity has been reported between the Striped Peak and Libby Formations (Harrison and Campbell, 1963). Obradovich and Peterman (1968) record a hiatus of about 200 m.y. in the sedimentation of the supergroup, which could be the time span of the hiatus between these formations. The same workers believe that three hiatuses occurred at about +1300 m.y., 1100 m.y. and 900 m.y. Sedimentation in the Belt geosyncline stopped at some time before 760 m.y., leaving a gap of 200 to 400 m.y. before the deposition of the Middle Cambrian Flathead Quartzite of northwestern Montana. As most of the Missoula Group of the Belt Supergroup is absent in the Lakeview area, it can be assumed that a longer time interval occurred between the deposition of the youngest Belt unit and the Gold Creek Quartzite (similar in age to the Flathead Quartzite). Gentle folding and metamorphism affected the Belt sediments before the deposition of Paleozoic sediments. The Packsaddle, Cedar Creek, and Spider faults and the various shear zones (Fig. 2) were probably formed during these first tectonic movements.

Only Lower Paleozoic sedimentary units are represented in the Lakeview area. During Middle Cambrian time an encroaching, shallow sea deposited conglomeratic sandstone, then shale, and finally limestone over the tilted and beveled Precambrian rocks. There is no stratigraphic record between the Cambrian and the Pleistocene.

Near the end of the Mesozoic Era, probably in Late Cretaceous time (Harrison and Jobin, 1965), the Kaniksu Batholith and related bodies were emplaced. In the Lakeview area, a pluton (Pl. 1), believed to be of this age, was accompanied by block faulting and vertical readjustment along some of the pre-existing fractures. Shearing, thrusting and normal faulting were followed by intrusion of younger mafic dikes as a final stage of tectonism and readjustment. Also, pre-existing fractures and shear zones were filled by quartz and sulfide minerals.

During the Pleistocene Epoch, a continental ice sheet advanced across north Idaho damming the Clark Fork valley, and another southward along the Pend Oreille Lake basin. Several smaller lobes moved eastward from the Pend Oreille basin, damming Gold Creek, North and South Twin Creeks, and other smaller tributaries. Alpine glaciation in nearby mountains accompanied the continental glaciation. Poorly developed cirques are present at the headwaters of several streams (sec. 7, T. 53 N., R. 1 E). Since the retreat of the ice, the streams have been eroding through the Pleistocene deposits, exposing the underlying bedrock in several places.

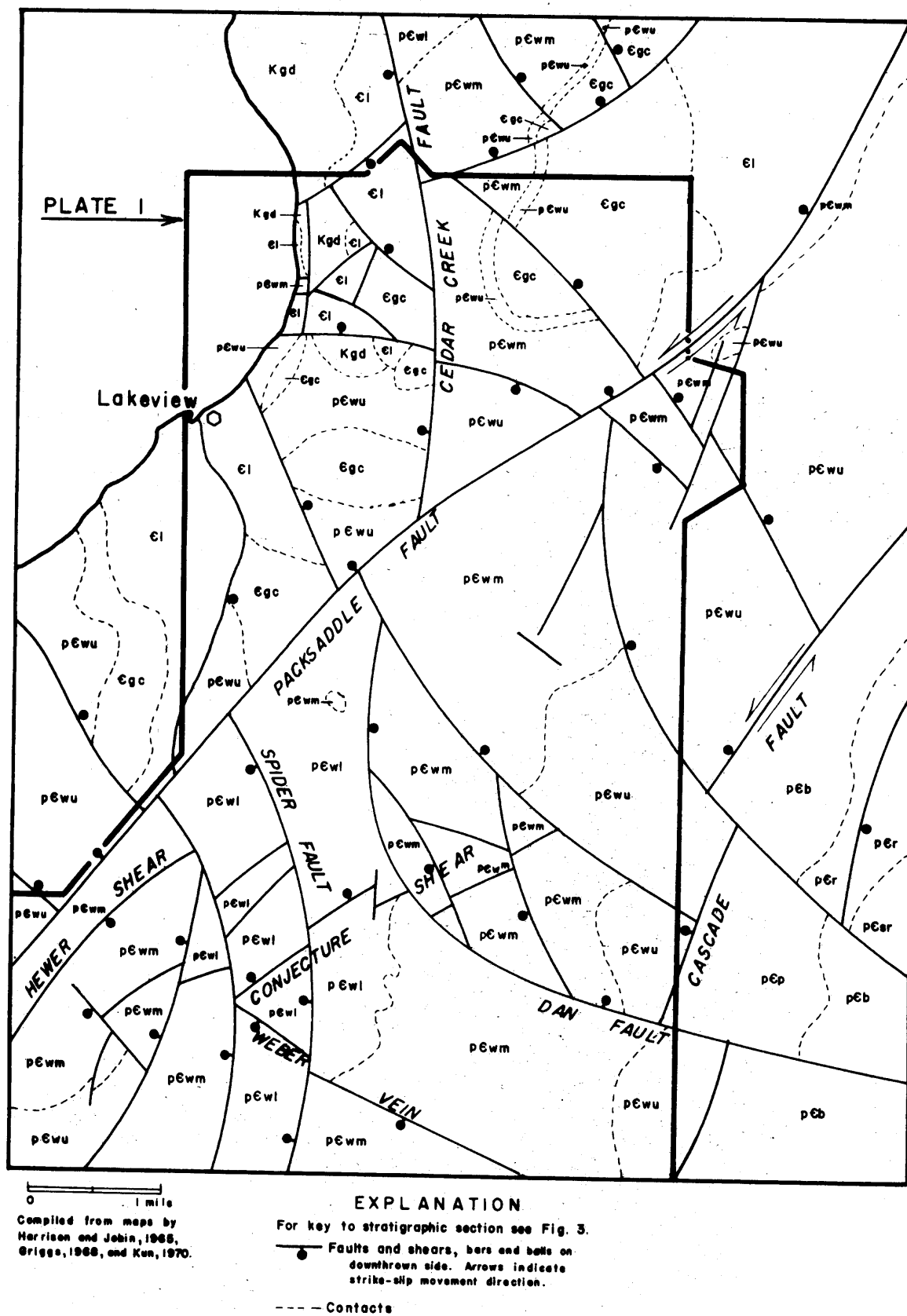


Figure 2. Generalized geologic map of the Lakeview area, Idaho.

STRATIGRAPHY

The rocks exposed in the Lakeview quadrangle are for the most part low-grade metasedimentary rocks of the Belt Supergroup of Precambrian age, and sedimentary rocks of Cambrian age (Fig. 3). These rocks have been intruded and partially replaced by granodiorite, lamprophyre-diorite dikes, sulfide, and quartz veins. Glacial deposits mantle the high cirques and major valleys. Alluvium and mass wasting deposits of Recent age overlie the glacial deposits.

Belt Supergroup

The Precambrian Belt Supergroup in the Lakeview quadrangle has a thickness in excess of 10,000 feet. In the Clark Fork quadrangle, a minimum thickness of 38,000 feet has been reported (Harrison and Jobin, 1963). The difference may be explained by the underlying igneous rocks, presumably marginal outliers of the Kaniksu Batholith, which have partially displaced and stopped the lower Belt formations in the Lakeview area (Figs. 2 and 3).

Only the Wallace Formation is recognized on the surface in the mapped area (Pl. 1), but the St. Regis and possibly the Revett formations were encountered at depth in the Conjecture Mine shaft and workings (private report, Federal Uranium Corporation, 1964). The Striped Peak Formation, which overlies the Wallace Formation to the north and east of the mapped area, was reportedly also found in the western part of the Lakeview quadrangle by Griggs (oral communication, 1967), and by Huntsberger (oral communication, 1968). Boulders and cobbles of Striped Peak siltites are found close to the base of the Cambrian Gold Creek Quartzite, on Green Mountain.

The Wallace Formation in the Lakeview area is made up of four different lithologic successions which are interbedded and transitional:

1. fine-grained quartzite: usually a tan quartzite or coarse-grained siltite very thinly bedded, sometimes calcareous or dolomitic.
2. light gray or green dolomitic and argillitic siltite: very thinly bedded, dolomitic, seldom calcareous, greenish siltite.
3. laminated black argillite: very thinly laminated argillite and fine-grained siltite, dark gray or black, very seldom calcareous.
4. Carbonate rocks: thin bedded, dark gray to dark green limestones and dolomites, usually interbedded with non-calcareous siltites and argillites.

Green to gray-green, very thin-bedded siltite and argillitic siltite are abundant in several stratigraphic horizons, making it difficult to place contacts between the members of the Wallace Formation. Several formations of the Belt Supergroup have repetitions of groups of beds. This is particularly evident in the Upper Member of the Wallace Formation where alternating beds of argillites, siltites and limestone form 30 to 50-foot thick units. These units are repeated throughout the 2500 feet of the Member.

The only fossils were found in the calcareous beds of the Wallace Formation and were stromatolites. Ross and others (1963) mention the possible existence of brachiopod casts in the Belt Supergroup of Montana. Some of the green siltite beds in

the Lakeview quadrangle have similar sedimentary structures. "Molar tooth" structure, formed by the differential weathering of certain limestones, thus giving it a furrowed appearance, is common in the calcareous beds of the Wallace Formation. Mud crack casts, ripple marks, load casts, boudins, and salt-crystal casts are also common throughout this formation.

It is of interest to note the average modes of the Belt rocks as obtained by Harrison and Jobin (1963). The quartz content varies between 51% (in quartzites) and 25% (in limestones and dolomites). The combined potassium and plagioclase feldspar content varies from 20% in quartzites to 11% for the calcareous rocks. Sericite and chlorite account for 56% of the total mode in argillites and only 15% in limestones and dolomites. The carbonate content is very low in the clastic rocks (1%-3%) and high in the limestones and dolomites. It is unusual to find fine-grained clastics with quartz, feldspars and micas as main constituents and no defined clays visible. Even the calcareous rocks contain abundant feldspars.

Ravalli Group

Calkins (1909) described the Burke, Revett, and St. Regis formations as the Ravalli Group. Although none of these three formations appear to crop out in the mapped area, the St. Regis Formation is believed to occur in the Conjecture mine workings. Good exposures exist in the Packsaddle Quadrangle and the Lakeview 15 minute Quadrangle (Fig. 2).

The Burke Formation, found to the north in the Packsaddle Mountain area (Harrison and Jobin, 1965) and to the east, just outside the boundaries of the Lakeview 7½ minute quadrangle (Griggs, 1968), consists principally of very thinly interbedded, dark-gray siltite and green, silty argillite.

The St. Regis Formation consists of characteristic and distinctive interlaminated purple argillitic siltites with green argillites or siltites. It is abundantly exposed to the north of Lakeview, outside the mapped area where it contrasts sharply with the underlying Revett Quartzite and the overlying calcareous lower Wallace Formation. The purple color, characteristic of the St. Regis Formation is not consistent and tends to change to a pale green or gray color in hydrothermal or metamorphosed areas. The thickness of the St. Regis Formation east of Lakeview is estimated by Griggs (oral communication, 1967) to be about 1,000 feet.

Waste rock from the Conjecture Mine shaft contains much purple and green argillite and siltite, very similar in appearance to the St. Regis found in the Packsaddle Quadrangle. The rock is an argillitic siltite, crossed by abundant clay and sulfide veinlets, and containing euhedral pyrite crystals. The matrix consists of very fine clay-mica minerals surrounding well-rounded quartz grains. No visible calcareous minerals have been found.

Wallace Formation

The Wallace Formation is about 7,500 feet thick at Lakeview and has been subdivided into three distinct members with gradational contacts. Exposures are few in most of the mapped area and consequently, the details of the stratigraphic succession are poorly known. Several distinctive rock types have been found. They are, in order of decreasing abundance, a) black and green or gray, thinly interlaminated, argillite and siltite, b) green siltite, c) gray, silty dolomite, d) calcareous, greenish-gray, argillitic siltite, e) massive, dark gray limestone, f) massive, white or brown quartzite, g) laminated green argillite.

Lower Member The Lower Member of the Wallace Formation consists of limestones and dolomites with interbeds of calcareous, greenish siltites and argillites. The best exposures of this member can be found along the roads in secs. 23 and 26, T. 53 N., R. 1 W. The estimated thickness of this member in the vicinity of the Conjecture Mine is 2,000 feet.

The Lower Member changes from waxy, green argillites and siltites at the base, through limestones, dolomitic limestones, and calcareous siltite in the middle, to calcareous black argillite and green siltite at the top. White dolomitic quartzite forms sparse beds within the carbonate rocks, especially within the limestones and dolomite. Most of the Lower Member is very thinly bedded, varying from thin bedded to laminated.

The dolomitic limestone layers commonly have irregular pods and veinlets of calcareous material forming swirls. Differential weathering of these, as well as the stromatolites, produce swirled furrows which have been called "molar tooth" structures by Harrison and Jobin (1963) and Ross and others (1963). "Molar tooth" limestones have been found only in the Lower Member of the Wallace Formation.

The Lower Member differs from the underlying St. Regis Formation in the content of calcareous minerals. Whereas few calcareous minerals have been reported in the St. Regis Formation, they form the bulk of the Lower Member of the Wallace Formation. The contact is transitional and its position varies according to the criteria of different authors (Harrison and Jobin, 1963, and Griggs, 1968). The contact between the Lower and Middle Members of the Wallace Formation is also transitional and quite arbitrary, usually placed where the ratio of carbonate minerals is equal to the silt-sized quartz.

The Lower Member has microcrystalline rounded quartz and calcite, in a clay and calcite matrix. Brown stringers of carbonaceous material form swirls throughout the matrix.

Middle Member The Middle Member of the Wallace Formation consists of thinly and very thinly laminated black argillite with interbedded green argillitic siltite. Most rocks were found to be slightly dolomitic. The best exposures are on the ridges between Kick Bush Gulch and North Gold Creek in the central part of the quadrangle (Pl. 1). The thickness of the Middle Member is 3,000 feet.

In thin section the Middle Member argillite consists of a microcrystalline quartz with clay matrix, crossed by numerous layers of clay and carbonates. Microfracturing is visible on a freshly fractured or cut surface of most argillites. In the vicinity of the Idaho Lakeview Mine, and probably in other mineralized areas as well, relict sulfides can be found along the microfractures and in the quartz matrix.

Due to the lack of continuous, good exposures in the Lakeview area, the contact between the Lower and Middle Members was placed where dark gray and black, very thinly laminated argillites with non-calcareous green argillitic siltites, became predominant over calcareous beds. The contact between the Middle and Upper Members was placed at the base of the transitional zone between the two members, where the first limestone beds appear and the first repetition of groups of beds can be seen.

Upper Member The Upper Member of the Wallace Formation consists of a sequence of alternating layers of the rock types found in the two lower members. The

principal rock types are green calcareous argillite and siltite, green and tan silty limestone, and gray dolomitic siltite. Alternating layers of argillites, siltites, and limestones form units of about 30 ft. thickness, which are repeated throughout this member.

Because of the thin-bedded argillites and siltites, the Upper Member weathers easily and rapidly, with the argillite and siltite fragments covering many outcrops. Most areas underlain by the Upper Member of the Wallace Formation have a thick soil and vegetation cover on the northern slopes and barren, scree and talus-covered slopes on the southern slopes.

The best exposures of the Upper Member are on the east edge of the quadrangle along the Bunco Road roadcuts. The thickness of this member in Lakeview and adjacent areas is estimated to be about 2,000 to 2,500 feet. Total thickness of this member cannot be measured in the Lakeview quadrangle because the units are gradational into the Middle Member of the Wallace Formation, and the top is exposed only outside the mapped area (Harrison and Jobin, 1965, Griggs, 1968).

Cambrian Rocks

Three Cambrian formations have been recognized and named by Sampson (1928) in the Lakeview area. These names, accepted by the U.S. Geological Survey (Wilmarth, 1938), are: Lakeview Limestone, Middle Cambrian; Rennie Shale, Middle Cambrian; Gold Creek Quartzite, Lower or Middle Cambrian.

The thickness of the Cambrian formations is about 1600 feet, with the quartzite unit 500 feet thick, the shale unit 100 feet thick, and the limestone unit 1,000 feet thick. It is interesting to note that the Cambrian sediments are found only west of the Packsaddle Fault and east of the wide shear zone passing through Griffith Peak, Magee Peak, Lamb Peak, and Boundary Peak in the eastern part of the Lakeview 15 minute quadrangle (Griggs, 1968). It is possible that the faults formed a series of semi-parallel horsts and grabens which were partially flooded by a shallow Cambrian sea. The sedimentary sequence strongly suggests a progressively deeper sea with abundant alluvial material being deposited in it.

Gold Creek Quartzite

The Gold Creek Quartzite is exposed in the north part of the Lakeview Quadrangle, capping the highest ridges in the mapped area, and forming prominent cliffs on the south side of Green Mountain.

The Quartzite lies unconformably upon the lower part of the Upper Member of the Wallace Formation. The surface of the unconformity was not found, but beds immediately above and below show a difference of about 10 degrees in the magnitude of dip and a similarity in the strike direction. The quartzite is estimated to be 500 to 600 feet thick. It has a thin, lenticular basal conglomerate, overlying the Upper Member of the Wallace Formation. The conglomerate contains mostly well-rounded quartz pebbles, presumably originating from Belt rocks, but it also contains some jasper pebbles which have no known local source (Harrison and Jobin, 1965).

The rest of the Gold Creek Quartzite is a very thick-bedded, thinly crossbedded quartzite, with graded bedding marked by dark purple (Fe rich?) layers. It is slightly feldspathic in places, and fine to coarse grained. In thin section a mosaic texture of pure equigranular quartz with quartz overgrowths, and cemented by quartz, can be seen. Some iron staining and interstitial clay minerals are visible.

Rennie Shale

The Rennie Shale is a thin, lenticular, transitional unit between the quartzite and limestone. No outcrops of this formation were found in the area mapped. The type locality (Sampson, 1928) is at the headwaters of the North Branch of North Gold Creek, outside the Lakeview Quadrangle to the northeast, where it has a reported thickness of 100 feet. Sampson (1928) and Harrison and Jobin (1965) report Middle Cambrian trilobites and brachiopods in the Rennie Shale.

Lakeview Limestone

The Lakeview Limestone is well exposed in and around the town of Lakeview. It forms prominent cliffs along the lake shore.

The lower part of the formation is light to dark gray or black, very thick bedded with interbedded shaly members. It becomes thin-bedded and mottled towards the center and top of the exposed formation.

In thin section the Lakeview Limestone contains abundant calcite veinlets, invertebrate fossil fragments and some pyrite and possibly chalcopyrite. Calcite pods are found in samples from the old limestone mine around the Vulcan Mine, where contact metamorphism is more intense. Some of the Lakeview Limestone is bleached as a result of metamorphism. The limestone is reported (Savage, 1967) to be of commercial quality for lime production. The mine is near the contact with intrusive rocks, and contains abundant calcite veins and black, powdery material.

The top of the Lakeview Limestone is missing because of erosion, but the thickness of the formation is reported (Griggs, 1968) to be over 2,000 feet near Lakeview.

Metamorphism and Rock Alteration

Most sedimentary rocks in the area have been at least slightly metamorphosed. The Belt rocks have been regionally metamorphosed slightly, with the exception of the margins of the Hewer shear, where stronger effects can be observed. The Cambrian sediments also show varied effects. The Lakeview Limestone varies from fresh to highly metamorphosed skarn and the Gold Creek Quartzite varies from fresh orthoquartzite to a slightly metamorphosed rock.

The clastic non-calcareous members of the Wallace Formation contain mainly feldspars, quartz, and micas. Chlorite and biotite replace sericite. Gillson (1929) reports the presence of recrystallized quartz, microcline, tourmaline, zircon and apatite in zones of contact metamorphism near the mouth of Granite Creek, north of Lakeview. Along the Hewer shear, metamorphism of the Wallace siltites and argillites has produced hornfelsic textures with prominent feldspar, amphibole, and biotite crystals.

A contact of the Gold Creek Quartzite with the granodiorite is exposed 1500 ft. east of the Vulcan Mine. The quartzite is more red than usual with abundant magnetite and ilmenite, altering to limonite. Gillson (1929) reports the presence of minute biotite flakes, tourmaline, and andalusite in the metaquartzite northeast of Bayview. Quartz overgrowth of quartz crystals, as well as the development of muscovite at the expense of sericite, is common in the quartzite.

The calcareous rocks of the area show a greater range of metamorphism. White and green banding is present in the calcareous beds of the Wallace Formation to the east of Bernard Peak in sec. 18, T. 54 N., R. 1 W. The minerals contained in these green bands are, according to Gillson (1929), microcline, albite, diopside, epidote, and amphibole.

The Lakeview Limestone around the Vulcan Mine shows the highest degree of metamorphism in the entire district, probably because of the shallow depth to the contact with the underlying granodiorite. Contact metamorphism has changed the limestone from a normal gray to a white and a dark green marble. The white marble appears to be mostly recrystallized dolomite and is found replacing massive dolomitic limestone beds. The dark green rock is found very close to the limestone-granodiorite contact (200 ft. west of the Vulcan Mine) and appears to be a silicated limestone. Gillson (1929) described the presence of epidote, phlogopite, fluorite, ankerite, scapolite, and other minor minerals in the same locality. Disseminated pyrite is abundant in the metamorphosed limestone, but is scarce elsewhere in the same formation. In the Old Limestone Quarry (sec. 34, T. 54 N., R. 1 W), the rock is unaltered at the portal but becomes increasingly dark and veined by calcite as the limestone-granodiorite contact is approached.

It is concluded from Gillson's (1929) data that contact metamorphism in the Cambrian rocks ranges from the epidote-hornfels to the hornblende hornfels facies (Fyfe and others, 1958). Regional metamorphism has altered most of the Belt rocks to the quartz-albite-muscovite-chlorite subfacies of the greenschist facies.

Alteration of the metasediments in the vicinity of orebodies and mineralized fractures is manifested by bleaching of the wallrocks and an increase of disseminated pyrite towards the veins. The halos of alteration in the Coeur d'Alene district have been studied, but they are not useful in exploration, because hydrothermal solutions are thought to have passed through the plumbing system prior to the main stage of ore mineralization and ore solutions did not always follow the same channels. Conversely, many channels were filled directly with sulfide-bearing solutions without having been affected by early hydrothermal fluids (Ridge, 1968). These effects are noticeable in the Lakeview district, where bleaching and pyritization of the wallrock is very pronounced around the Conjecture mine and some of the fractures in the north-central part of the mapped area, while parts of the Conjecture and Weber shears are essentially unaltered.

Surficial Deposits

The surficial deposits in the area are presumably of Quaternary age and include glacial, alluvial, lacustrine, mass gravity and colluvial deposits. Glacial silt, sand, and gravel, poorly to moderately well-sorted and stratified, partially cover the floors of most valleys and basins. These deposits have been deeply cut by post-glacial streams.

Glacial Deposits

Glaciofluvial and glaciolacustrine deposits are abundant in most of the valleys of Gold Creek, North Gold Creek, Kick Bush Gulch, Chloride Gulch, and the valleys and flats south of North Twin Creek (Pl. 1). The deposits include till and moderately well-sorted, thin-bedded silts, sands, and gravels that were deposited in lakes marginal to the glacier that occupied the Pend Oreille Lake basin during Pleistocene time. These

THICKNESS	SYMBOL	FORMATION & MEMBER	LITHOLOGY
FEET			
+2000	 €l rere	Lakeview Limestone	Thick bedded limestone with interbedded shaly members; fissile shale on bottom.
500	 €gc	Gold Creek Quartzite	Conglomerate & quartzite.
UNCONFORMITY			
2500	p€wu	Upper Member	Alternating layers of argillites, siltites & limestones forming units of 30' thickness.
3000	p€wm	Middle Member	Thinly laminated black argillite with interbedded green argillitic siltite.
2000	p€wl	Lower Member	Thinly bedded limestones & dolomites with interbedded greenish siltites & argillites.
1500	p€sr	St. Regis Formation	Purple argillitic siltites with interbedded, green argillites. (Griggs, 1968).
2500	p€r	Revett Formation	Gray and buff quartzites. (Griggs, 1968).
3000	p€b	Burke Formation	Very thinly interbedded, dark gray siltite and green silty argillite. (Griggs, 1968).
+10000 FEET	p€p	Prichard Formation	Black and gray, very thin-bedded, argillite with some interbedded siltite. (Griggs, 1968).

Figure 3. Stratigraphic section of Precambrian and Cambrian rocks in the Lakeview quadrangle, Idaho.

deposits are several hundred feet thick in the northwestern part of the mapped area. Hanging valleys along the lake shore, at elevations of 3,000 to 3,200 feet record the presence of ice at least 1,000 feet above the present water level. Glacial striations on the granodiorite between the Twin Creeks indicate a north-south movement.

Till is also present in the headwater areas of most streams at elevations above 4,000 feet. The bowl-shaped topography in these areas strongly suggests the presence of cirques that have been overgrown by dense vegetation since the retreat of the ice. Several soil horizons have developed and concealed most of the till, but in roadcuts and trenches around the Silver Leaf Mine, till can easily be recognized.

Post-glacial Deposits

Landslide, alluvial and talus deposits comprise the post-glacial deposits. Two major landslides are present in the northern part of the quadrangle in sec. 6, T. 53 N., R. 1 E, and sec. 34, T. 54 N., R. 1 W (Pl. 1). The smaller, a narrow slide, left a scar of about 300 feet in elevation, on the southern side of North Gold Creek, close to the eastern edge of the quadrangle. The larger, obviously a recent rock slide, is on the lake shore about $1\frac{1}{2}$ miles north of Lakeview and is controlled by two faults. The scar appears much larger on aerial photographs than as seen from the ground or from the lake. Several other small slides occur along the shore.

Talus slopes are prominent at the base of the cliffs of limestone along the lake shore, on the north-eastern end of the Packsaddle Fault scarp, and about one mile south of Lakeview along the main road. The south-western slope of Green Mountain is covered by talus from cliffs of the Gold Creek Quartzite.

The alluvial deposits are mainly reworked glacial debris deposited in new and abandoned stream channels. The shoreline has many pebble beaches which are of post-glacial age. Some rounded boulders of basalt similar in composition to Columbia River lava flows of northern Idaho can be found at elevations of up to 3,500 feet.

INTRUSIVE ROCKS

All igneous rocks in the mapped area are intrusions. They include a granodiorite stock and mafic dikes. The age of the pluton is probably Cretaceous, although no radiometric age determinations are available. It is possible that some mafic dikes are Precambrian and related to the Purcell Sills.

Granodiorite

Granodiorite crops out in the northwestern part of the mapped area (Pl. 1), forming bold cliffs along the shore line and rounded outcrops south and east of the Vulcan Mine. The intrusive rock is monolithologic and appears to be part of one stock. The granodiorite weathers with limonite staining on exposed surfaces. Joints appear as prominent features because the red-brown staining is more intense on joint surfaces than the rest of the outcrops. Limonite often masks the gray or mottled black and white appearance of the granodiorite in outcrops.

In hand specimen (Fig. 4), the granodiorite appears highly porphyritic, with a purplish tint on the fresh surfaces. The phenocrysts include euhedral labradorite, with occasional twinning and anhedral quartz crystals; the matrix is composed of biotite, quartz, hornblende, feldspar, and pyrite. Iron staining covers at least one side of most broken pieces, but cannot be detected on fresh surfaces.

In thin section (Fig. 5), the granodiorite is very coarse-grained, holocrystalline, porphyritic and shows more alteration than is apparent in hand specimens. The essential minerals are plagioclase feldspar, orthoclase, quartz, hornblende and biotite, with minor calcite, epidote, zoisite, apatite, and zircon. The plagioclase feldspars often show prominent zoning, and Carlsbad and albite twinning, with most crystals being altered to sericite and other clay minerals. The composition of a homogeneous plagioclase feldspar phenocryst is approximately An_{34} as determined by the Michel-Levy method. The composition of the plagioclase feldspars in the matrix could not be determined accurately. The quartz crystals are rounded and usually fresh, with some showing undulatory extinction. Orthoclase crystals are corroded by the matrix, making them anhedral and "ragged" looking. Alteration of orthoclase is mainly to sericite. Hornblende and biotite are disseminated throughout the groundmass. The hornblende is faintly pleochroic from pale green to dark green, and is found in prismatic crystals, strongly replaced by calcite, epidote, biotite, chlorite and quartz. It is poikilitic, shows some twinning, moderate birefringence, large axial angle, and an extinction angle of 23° . The biotite is strongly pleochroic from reddish-brown to dark brown, with high birefringence and parallel extinction, which is sometimes masked by intense chloritization. Most biotite crystals are partly replaced by chlorite.

The average mode of the granodiorite is plagioclase feldspar 30 percent, quartz 30 percent, orthoclase 20 percent, biotite 8 percent, hornblende 7 percent, and accessory minerals 5 percent. According to Travis' (1955) descriptive classification of igneous rocks, the above described rock is a granodiorite or a hornblende granodiorite.

No pegmatites were found cropping out in the Lakeview area, although pegmatites appear frequently in other facies of the Kaniksu Batholith (Savage, 1967).

Mafic Dikes

The mafic dikes are usually associated with fractures as in the case of the Spider Fault (Fig. 2). They are not found in outcrops, but rather in fresh cuts or underground. All the samples collected are of lamprophyric composition and texture. Whether these dikes are similar to highly altered diabases as reported by Anderson (1930 and 1947) from the Clark Fork area, or lamprophyres altered by later hydrothermal activity possibly contemporaneous with ore deposition, remains to be determined.

Mafic dike boulders can be found close to some faults and shear zones, and the dikes can be seen in bulldozer cuts, in the shear zones of the main level of the Weber Pit and Mine, and on several levels of the Conjecture Mine (Pl. 4 and 5). Fresh hand specimens are usually olive green but turn greenish-black after weathering. Biotite and hornblende crystals can be easily detected with the naked eye, but study of the matrix requires the use of a microscope. The rock weathers very rapidly, so that fresh specimens can be obtained only from new cuts or from underground. The mafic dikes are probably abundant in the Lakeview area, but being easily weathered, their detection is restricted almost exclusively to cuts and mine workings.

In thin section, (Fig. 6) the rock appears intensely altered with large euhedral hornblende and biotite crystals, very altered plagioclase feldspar crystals and relicts, augite, quartz, idocrase, zoisite, leucoxene-ilmenite, calcite and pyrite. The hornblende is pleochroic from light greenish-brown to dark reddish-brown, and forms prismatic crystals, has moderate birefringence, extinction angle of 28° , some twinning, and a large axial angle. The augite is colorless, having moderate birefringence, extinction angle of 32° , and a large axial angle. Augite appears to be almost completely replaced by hornblende. Biotite is pleochroic from light reddish-brown to dark brown, strong birefringence, and parallel extinction. Most grains are chloritized. The texture is automorphic granular (lamprophyric), with alteration of most of the feldspar to sericite, replacement of biotite by chlorite, augite by hornblende, and hornblende by leucoxene. Because of the intense alteration it is hard to make a modal study of the dikes. An estimate of the mode is hornblende 35 percent, biotite 20 percent, altered plagioclase and relicts 15 percent, augite 10 percent, and replacement and accessory minerals 20 percent. Following the descriptive classification by Turner and Verhoogen (1960), the mafic dikes can be named spessartites because of their composition and proximity to a granodioritic pluton.

The mafic dikes contain sulfides in the Weber and Conjecture mines. Similar dikes reportedly cut granodiorite intrusions in the Cabinet range and Purcell Trench (Anderson, 1930, p. 36) to the north of Lakeview.

Age

The mapped area is partly surrounded on three sides by large intrusions. To the north, the Nelson Batholith and associated stocks have been mapped in northern Idaho and British Columbia, to the west the Colville and Kaniksu Batholiths crop out in eastern Washington, the Kaniksu and Selkirk Batholiths in the Idaho panhandle, and to the south the Gem Stocks are found north of Wallace, Idaho.

The granodiorite and related intrusive rocks east of Pend Oreille Lake are considered by many previous workers as part of the Kaniksu Batholith (Gillson, 1927;

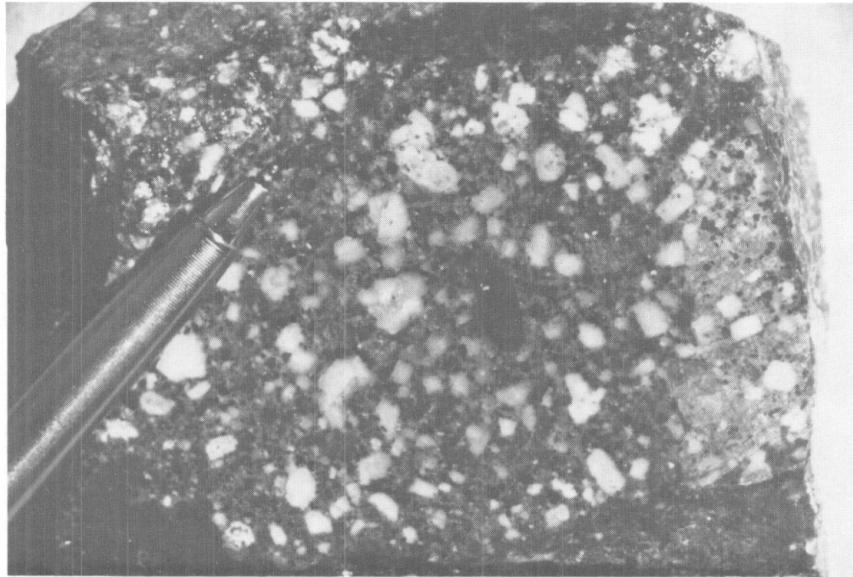


Figure 4. Granodiorite hand specimen showing porphyritic texture.



Figure 5. Granodiorite thin section of the specimen from Figure 4, showing zoned plagioclase feldspar, quartz and corroded orthoclase phenocrysts, sericite, biotite, and pyrite. Crossed nicols.



0.5 mm

Figure 6. Lamprophyre thin section from outcrop in Weber Pit. Euhedral hornblende, and plagioclase feldspar. The plagioclase is almost completely replaced by sericite.

Anderson, 1930; Savage, 1962 and 1967; Harrison and Jobin, 1963 and 1965). From petrographic evidence it is the belief of this author, and others (Reid, oral communication, 1969; Anderson, 1930 and 1947), that the Kaniksu, Idaho, Colville, and Nelson Batholiths are of similar age and genetically related to each other.

The ages determined on various intrusions in the region range from 110 m.y. to 70 m.y. (Kun, 1970). The Idaho and Nelson batholiths have marginal stocks as young as 11 ± 1 m.y.

Intrusions may be grouped into four age groups: 130 m.y. and older, 90 to 115 m.y., 60 to 85 m.y., and 20 to 40 m.y. (Kun, 1970). Assuming that the age determinations are reasonably correct, several intrusive episodes could have affected the same areas. Reesor (1965) mentions the favorable structural setting for intrusions along the Purcell Trench, of which the Pend Oreille basin is a southern extension.

Lacking any age determination in the Kaniksu Batholith in the Pend Oreille region, it is reasonable to assume that the Kaniksu Batholith has a similar age to the Colville Batholith (99 ± 10 m.y.). The lamprophyre dikes are interpreted as being younger than the granodiorite stock.

STRUCTURE

Complex faults and shear zones, related mainly to the granodiorite intrusion, are the most prominent structural feature of the quadrangle (Pl. 1). The entire area is on the west flank of a large syncline, which has an axis located approximately 10 miles east of Lakeview (Griggs, 1968). Small drag folds with the axial surface parallel to the faults and shear zones surround the granodiorite outcrop at the Vulcan Mine. North-trending faults show major displacement, and contain little or no mineralization, while the east-trending shear zones show little displacement of adjacent strata and are usually fracture-filled by quartz and sulfide veins. Jointing is prominent throughout the Belt Supergroup and appears to be emphasized by weathering. A low-angle normal fault has been mapped north of Lakeview. This fault places the Lakeview Limestone directly on the Upper Member of the Wallace Formation. One prominent east-west joint system is present in the granodiorite. This appears to be cross-jointing because the trend is perpendicular to the lineation in the rock.

Faults

Packsaddle fault, the major fault in the area, separates an intricate mosaic of steep-sided fault blocks on the northwest from a simpler mosaic on the southeast (Pl. 1). Secondary faults, which bound the fault blocks, are very steep to vertical, as is shown by their nearly straight traces across a topographic relief for as much as 3,000 feet. In contrast, shear zones dip at angles of 45° and 70° , and trend to the northeast or southeast.

Packsaddle Fault

The Packsaddle fault has a left-lateral, strike-slip displacement of approximately 1,000 ft. and an estimated throw of at least 6,000 ft. It is barren of economic mineralization, although zones of silica enrichment as much as 200 feet wide surround the fault. The vertical displacement along the fault is estimated from stratigraphic correlation of beds on both sides of the fault, in the northeastern and southwestern corners of the Lakeview Quadrangle (Pl. 2, sections AA' and CC'). In the northeastern corner of the Lakeview Quadrangle, the throw of the fault has been estimated by the offsets between the contacts of the Middle and Upper Members of the Wallace Formation on the south, and the contact between the Gold Creek Quartzite and the Lakeview Limestone on the north side of the fault (sec. 31, T. 54 N., R. 1 E). In the southwestern part of the Lakeview Quadrangle, the throw of the Packsaddle fault has been estimated from the offset between the lower, calcareous units of the Middle Member of the Wallace Formation and the east side and the central, argillitic and calcareous units of the Upper Member of the same formation on the west side (sec. 21, T. 53 N., R. 1 W.).

The strike-slip component of movement along the Packsaddle fault is difficult to determine since there are no displaced dikes that can be matched across the fault. The strike-slip can be estimated only from the offset of very steeply dipping or vertical cross faults on both sides of the Packsaddle fault which is hampered in many cases by thick vegetation and soil cover. By this means, a left-lateral, strike-slip movement is estimated to be between 500 and 1,000 feet.

The Packsaddle fault appears to be related to the earliest metamorphism and

tectonic activity affecting the Belt Supergroup. The lower part of the Upper Member of the Wallace Formation is the youngest Belt rock on the west, and is unconformably overlain by Middle Cambrian sediments. The upper part of the Wallace Formation and the younger Striped Peak Formation, which has a thickness of about 2,000 ft. (Griggs, 1968) east of the mapped area, is not found on the surface in the Lakeview Quadrangle. East of the fault, and outside the mapped area, a complete section of the Upper Member of the Wallace Formation and the Striped Peak Formation is found (Griggs, 1968; Harrison and Jobin, 1965). This suggests that the fault-block east of the Packsaddle fault was a topographic low during the Late Precambrian while the fault-block west of the Packsaddle remained as a topographic high during the Late Precambrian and Early Cambrian. This situation reversed during the Middle Cambrian when there was deposition to the west of the Packsaddle fault. The basal conglomerate of the Gold Creek Quartzite appears to have originated from beach deposits, in a shore-line environment. Thus, it is possible that the fault-block to the east of the Packsaddle fault remained as a high, and as a source of clastic material during the Middle Cambrian. Post-Cambrian events in relation to the fault, are difficult to establish due to the stratigraphic gap between the Cambrian and Pleistocene. Paleozoic faulting has been inferred by Anderson (1930, p. 20-22) and other workers (King, 1970, p. D6). The only evidence of further movement along the Packsaddle fault is the silicification of the wall rocks, immediately adjacent to the fault. The Gold Creek Quartzite, close to the fault has a higher limonite and sericite content, as compared to fresh unaltered quartzite, and is stained brown and erodes easily. No sulfide mineralization has been found along the Packsaddle fault trace, and the Hewer shear that previous workers have associated with this fault (Sampson, 1928; Savage, 1967) has been found in the present investigation to be a separate fracture.

Other Faults

A pronounced grid of two sets of faults striking approximately north and east, and intersecting at angles between 45 and 80 degrees is characteristic of the Lakeview area. The size of the blocks thus bounded is directly proportional to the distance from the intrusive granodiorite (Pl. 1). In the northwestern corner of the mapped area, abundant small faults and blocks, with the rock affected in various degrees by metamorphism, are commonplace. The area of the blocks ranges from one-eighth to one-fourth sq. mile. In the northeast portion of the quadrangle and also to the south of the Packsaddle fault the blocks become larger, in places being divided by wide shear zones. Some are over one square mile in area.

Where outcrops are present, the strata on each side of the block faults show small drag folds. Many faults are surrounded by alteration halos due to sericitization, chloritization, silicification, and pyritization. Abrupt changes in lithology are apparent across many of these faults, especially north of Lakeview.

The faults are vertical or very steep as topography affects their surface traces very little. Horizontal displacement of some faults is in the order of 200 to 500 feet, as measured by displacement of Lakeview Limestone on both sides of some of the faults. Horizontal movement of the block faults appears related to the strike-slip movement of the Packsaddle fault, and is of small magnitude.

Block faulting has been related to the emplacement of the granodiorite stocks. The difference of many thousands of feet in structural rise from the east to the west of the area, accompanied by a stepping down of the blocks from west to east, suggests that the emplacement of the Cretaceous granodiorite pluton was effected partly by stoping (as evidenced by granodiorite overlain directly by intensely altered and metamorphosed Cambrian sediments, found to the north of Vulcan Hill and around Packsaddle Mountain (King, 1970) where the sediments should be thickest), and partly by upward

push as shown by some keystone blocks bounded by faults that converge upwards.

Shear Zones

The shear zones have average dips ranging from 45 to 70 degrees, and strike northeast and southeast. The width of the shear zones varies from a few feet to over 1,000 feet for the Conjecture shear (Pl. 1). Some attitudes and widths of shear zones can be seen in the Weber Pit, the Idaho Lakeview Mine, and the numerous bulldozer cuts in the Hewer, Conjecture and Weber shears (Pl. 1). Vertical displacement along the shear zones is very small, estimated at less than 300 ft. on the basis of surface and underground stratigraphy.

The shear zones are surrounded by hydrothermally altered rock containing trace amounts of sulfide or secondary oxide and hydroxide minerals, and are filled by gouge and mylonitic breccia, barren quartz veins, and massive and disseminated sulfides. Serpentine-like coating on slickensides along the Weber shear, in the pit of the same name, has been determined to be fibrous anthophyllite. Only an incomplete description of the rocks and structure within the shear zones is possible because they rarely crop out. Large-scale mapping of bulldozer cuts along the Conjecture shear showed the shear zones to be fractures filled by gouge and breccia, highly altered country rock, and massive quartz veins. Sulfide veins alternate with the quartz veins and (or) the breccia and gouge zones. The sulfide veins contain macroscopic galena, pyrite, native silver, and in smaller amounts, silver sulfosalts.

The difference between the shear zones and the block faults is striking. The block faults occur in narrow zones, sometimes surrounded by halos of hydrothermal alteration. They are vertical or steeply dipping and have a throw of several hundreds of feet. The shear faults are found in zones several hundred feet wide, with little or no vertical displacement, dip from 45 to 70 degrees, and are surrounded by wide, intensely altered zones. The block faults are barren except at the intersection with the shear zones, while the shear zones have contained the producing veins of the mining district.

Movement along the faults (Spider, Cedar Creek, etc.) appears to have occurred both before and after movement along the shear zones. No direct evidence exists to prove movement along the faults prior to the intrusion of the granodiorite. The faults, however, are apparently offset by the Packsaddle fault which separates two areas of different stratigraphy. The shear zones were probably formed contemporaneously with the intrusion of the pluton, and the faults offset the shear zones during the subsidence produced by the cooling of the granodiorite.

The shear zones appear to be prominent fractures which originated from an uplift and later relaxation, produced during the intrusion of the pluton (Fig. 7). The central fault block, bound by the Conjecture and Weber shears and the Spider fault, forms an upward wedge (Pl. 1 and 2) which could have originated from an uplift caused by stress from the intruding magma. The shear zones are thus visualized as having occurred in five stages:

- 1). Uplift, producing intense fracturing along the margins of the central blocks;
- 2). Emplacement of the first stage hydrothermal ore minerals (see "Mineralogy" and "Paragenesis");
- 3). Reopening of the dipping fractures produced by either a drop of the central block or uplift of the bounding blocks, accompanied by crossfaulting and emplacement of mafic dikes;

4). Filling of the newly produced voids within the shear zones by the second stage minerals, especially massive quartz;

5). Crystallization of hydrothermal minerals (quartz, pyrite, sulfarsenides, etc.) with adjustment along minor faults.

A similar process may have produced the central block bound by the Packsaddle fault and Hewer shear (Pl. 1 and section C-C" on Pl. 2). In this case major shearing apparently occurred only on one side of the block (see King and others, 1970, p. D14-D15).

Thrust Fault

A low-angle fault, visualized as a bedding plane thrust, has placed the Lakeview Limestone directly on the middle units of the Upper Member of the Wallace Formation, and has been mapped as a thrust fault (Pl. 1) north of Lakeview (secs. 26 and 35, T. 54 N., R. 1W.). Little can be said about this fault because it is covered throughout most of its extension by till and alluvial deposits. It appears to extend north into the Packsaddle Quadrangle, but has not been recognized as a thrust by Harrison and Jobin (1965) in their work. The fault is visible from the lake.

Joints

Joints are conspicuous in all the rock units of the area. Harrison and Jobin (1963) determined five joint sets in the Belt Supergroup in the Clark Fork quadrangle. Several of these sets have been found to be prominent in Lakeview, both in the Belt and Cambrian rocks. One set strikes west, another north, dipping vertically, and both appear to control partially the direction of several valleys. For example, Cheer Creek (secs. 11 and 12, T. 53 N., R. 1 W) flows north and west, crossing the Packsaddle fault, following the general direction of the two joint systems.

Joints in the granodiorite are especially conspicuous along the lake shore and on the main road north of Lakeview. Although insufficient measurements were obtained to make a structural-net plot, a general north-west strike with steep dips can be observed (Pl. 1). This joint attitude is perpendicular to a very faint lineation, produced by the alignment of phenocrysts and biotite crystals in the granodiorite. The jointing might be equivalent to "cross-jointing", explained by Balk (1959, p. 27) as a characteristic feature of the consolidation of magma.

Structural Interpretation

A comparison of magnetic intensities as reported by Savage (1962), known exposures of granodiorite, skarn, and intensity of metamorphism (Fig. 8) shows a distinct correspondence. The northwestern area of exposed granodiorite and skarn is the source of a positive magnetic anomaly, as would be expected from rocks with a relatively high content of magnetic minerals. The surrounding rocks show the effects of decreasing metamorphism, so the positive magnetic anomalies at the Vulcan Hill most likely represent a shallow, buried pluton (King and others, 1970). The area bounded by the Packsaddle fault and by the Cascade fault, is also an area of a positive magnetic anomaly which decreases to the south. This anomaly probably represents a body of granodiorite which has an upper contact plunging to the south. The cross joints in the granodiorite trend north to northwest (Pl. 1), coinciding in direction with the lamprophyre dikes, which could be genetically related to the underlying pluton. Mosaic-block faulting probably represents an adjustment to the tensional stress of the intrusion,

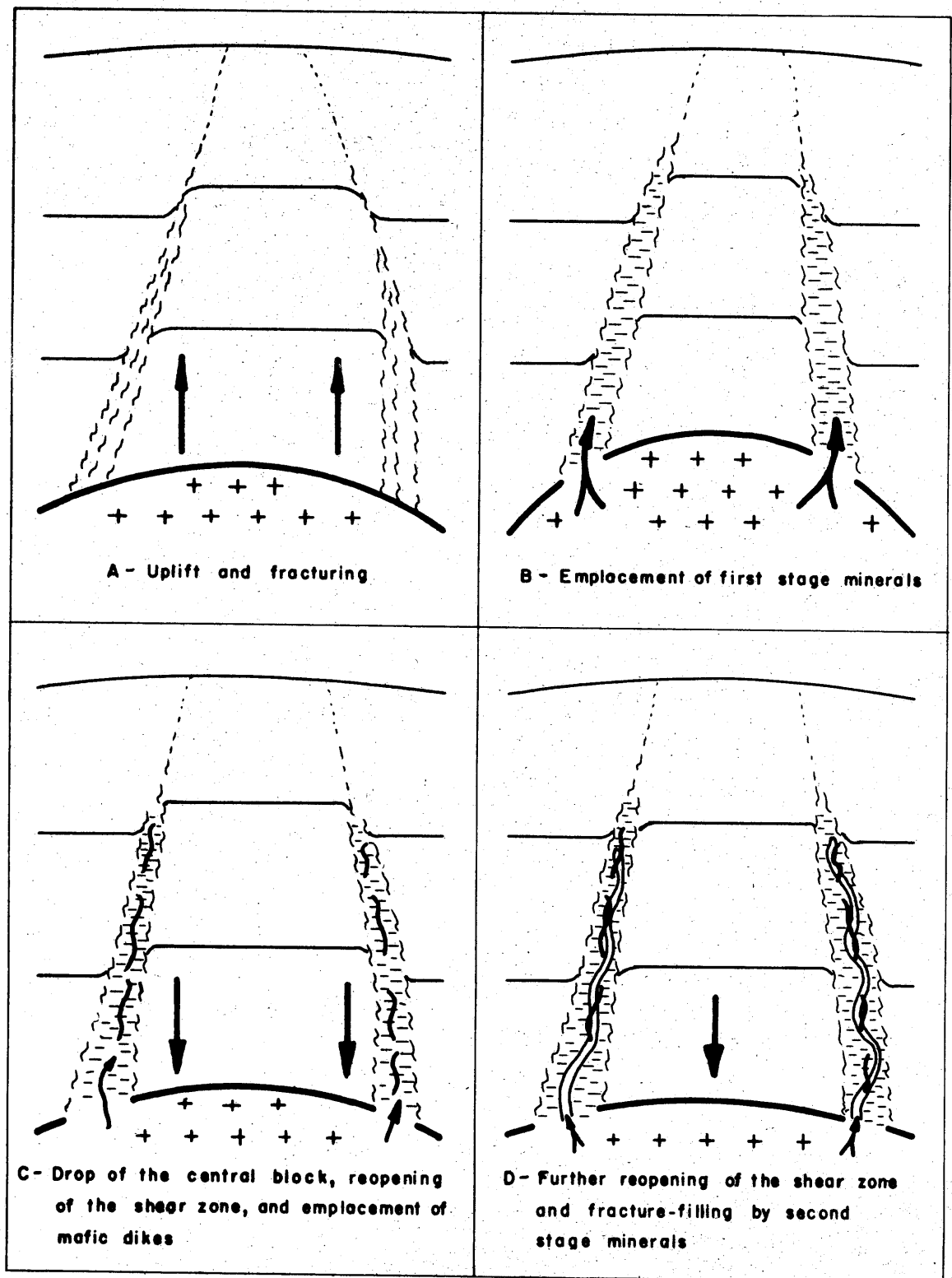


Figure 7. Schematic diagram showing the possible formation of some of the shear zones in the Lakeview mining district, Idaho.

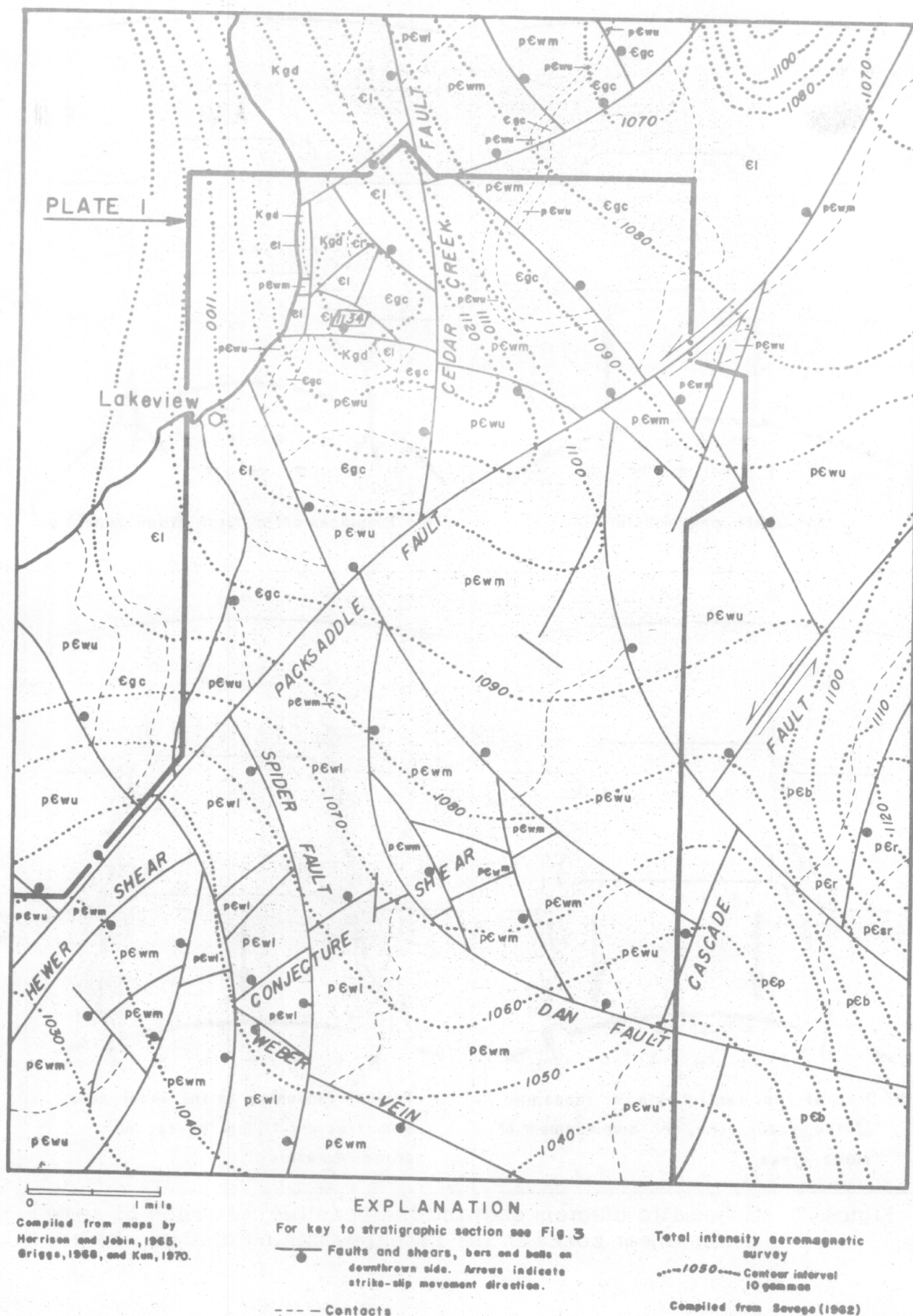


Figure 8. Combined geologic and total aeromagnetic intensity Map, Lakeview area, Idaho

reflected by very steep and vertical attitudes of the faults. Shear planes dipping at 45 degrees are found above salt domes, reflecting stresses of uplift. The only fractures dipping at 45 to 70 degrees are the shear zones (Pl. 1 and 2), which may represent the effects of uplift from the underlying plutons.

The shear zones may reflect tensional fractures formed by the uplift during the intrusion of the pluton and through which hydrothermal fluids may have risen and consolidated. The central block west of the Conjecture mine, may have originated by uplift followed by a withdrawal of support produced by a consolidating magma. Upon cooling of the magma, the blocks dropped and the remaining open fractures were filled by dikes. The newly emplaced mafic dikes were slightly affected by a second stage of mineralization which occurred when the shear zones reopened for the second time. Adjustment along minor faults was the last structural event affecting the newly formed orebodies.

The block faults probably represent the final adjustment of the rocks to stresses caused by the intrusion and cooling of the granodiorite combined with the movement along the Packsaddle fault. A close association of intrusion of mafic dikes and mineralized faults has been pointed out by previous workers (Sampson, 1928; Anderson, 1930; Harrison and Jobin, 1963). The dikes have been described as both preceding (Anderson, 1930) and following (Sampson, 1928) the ore emplacement. The ore-bearing shear zones are probably older, because they are offset by the block-faults.

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MINERAL DEPOSITS

The Lakeview mining district has produced an estimated \$2,000,000 in silver, lead, zinc, and gold since its discovery in 1888, until the early 1960's when mining was discontinued (Kun, 1968). The only existing production records are from private sources. No quantitative production records could be obtained from state or federal agencies.

During the field work, accessible mine workings were studied, and some were mapped. However, because most of the massive sulfide ore shoots have been either mined out, or are found only in the flooded or caved levels of the mines, much reliance had to be placed on information from other sources.

General Characteristics

The metallic mineral deposits of Lakeview are similar in their structural setting and mineralogy to the descriptions by Fryklund (1964) of the ores of the Coeur d'Alene mining district. The ores differ in their metal content and size of the orebodies. The silver content per ton of the Lakeview ores is much higher than those from the Coeur d'Alene district (Sampson, 1928) while the size of proven orebodies is much larger in the latter district. Characteristically, the ores in the Lakeview mining district are galena-carbonate-quartz fillings and replacements along shear zones. In addition to argentiferous galena, the deposits contain varying amounts of pyrite, sphalerite, tetrahedrite, and arsenopyrite, and minor and localized stibnite, hubnerite and various silver sulfosalts. Secondary enrichment of silver is of definite importance in most mines, where oxidized ores of high grade were the first and often only ones to be mined.

Most of the ore from the Lakeview mining district was mined from three fracture systems (Pl. 1 and Fig. 2):

- 1) the northeast-trending Conjecture Vein,
- 2) the southeast-trending Weber Vein,
- 3) the northeast-trending Hower Shear.

The ore shoots were enclosed in quartz and breccia in the shear zones, and were partly fracture-fillings and partly replacements similar to the orebodies in the Coeur d'Alene mining district. Most of the ores from the Lakeview mines were massive but there are disseminated sulfide minerals visible in the Weber Pit and on the main level of the Idaho Lakeview Mine. The host rock for most of the orebodies was the Middle and Lower Members of the Wallace Formation, as opposed to the Coeur d'Alene district where most orebodies are found in the lower part of the Ravalli Group and Prichard Formation (Ridge, 1968, p. 1423-1431).

Mineralogy

The ores in the Lakeview mining district can be separated into two major and one minor stages. The first and most important group represents a Coeur d'Alene-type stage of mineralization, and was followed by a later stage of ore deposition. The third group is made up of minerals of supergene origin, found in this study only in the veins of the Glasscock properties (S₂, sec. 35, T. 54 N., R. 1 W.).

First stage minerals

The early minerals in paragenetic order include arsenopyrite, early quartz, early pyrite, rhodochrosite and siderite, sphalerite, galena, and tetrahedrite. Arsenopyrite and siderite are visible only under the microscope while galena, pyrite, tetrahedrite, sphalerite, rhodochrosite, and quartz are usually visible with the hand lenses.

Arsenopyrite. Arsenopyrite (FeAsS) is found in samples from the Conjecture Mine and is reported from all the mines in the Lakeview mining district. It is found in stubby, elongated crystals of a maximum observed length of 4 mm. Arsenopyrite occurs in the silicified walls of veins, bordering early quartz-filled vugs and fractures. Arsenopyrite appears to be the earliest sulfide (Figs. 9, 10,), and is sometimes replaced by tetrahedrite and galena.

Early Quartz. Only minor amounts of quartz, occurring in small (5 mm. diameter), finely crystalline, and brecciated, masses, and partially replaced and cut by sulfides, appear to be of early deposition.

The early stage quartz (SiO_2) is visible in specimens from all the mines studied, but not in such a volume as the younger quartz, which fills large fractures. The early stage quartz was probably more abundant but has been replaced almost completely by later sulfides (Fig. 9). This replacement can be seen distinctly in samples taken from the Vulcan Mine (Fig. 11) and the 2,000 ft. level of the Conjecture Mine. Fryklund (1964) reports,

"...most of the quartz in the Coeur d'Alene veins was an original constituent of the country rock which was recrystallized in place."

Early Pyrite. Early pyrite (FeS_2) is a major constituent of all the veins of the district. Pyrite usually occurs as small euhedral crystals, very close to the vein edges, or disseminated in the country rock. Small amounts of massive pyrite have been found in the Glasscock mines, but are infrequent elsewhere.

The most common occurrence of pyrite is in disseminated euhedral and subhedral cubes of up to 5 mm. along the edge. Poikilitic and skeletal crystals, partially replacing feldspars or the country rock in general, are commonly found at the Glasscock properties, the Vulcan Mine, and some of the crosscuts on the main level of the Idaho Lakeview Mine. Early pyrite is partially replaced by galena in ore specimens from most mines. Anderson (1947) reports pyrite that has been engulfed by sphalerite and galena in the Clark Fork district, Idaho. In the Lakeview ores, masses of rhodochrosite and siderite contain no visible pyrite, while angular pieces of country rock engulfed by the carbonate minerals contain abundant, disseminated, euhedral pyrite crystals. I conclude that pyrite is one of the very early minerals in the Lakeview mining district, preceding the main event of ore deposition, and following the deposition of arsenopyrite very closely.

Colloform pyrite has only been found in one veinlet at the Glasscock property. Individual cubes cannot be observed even under high power magnification. The blebs are about one-half inch in diameter and are circular. Fryklund (1964) mentions that this type of pyrite was probably common in the veins of the Coeur d'Alene mines but was obliterated by later recrystallization.

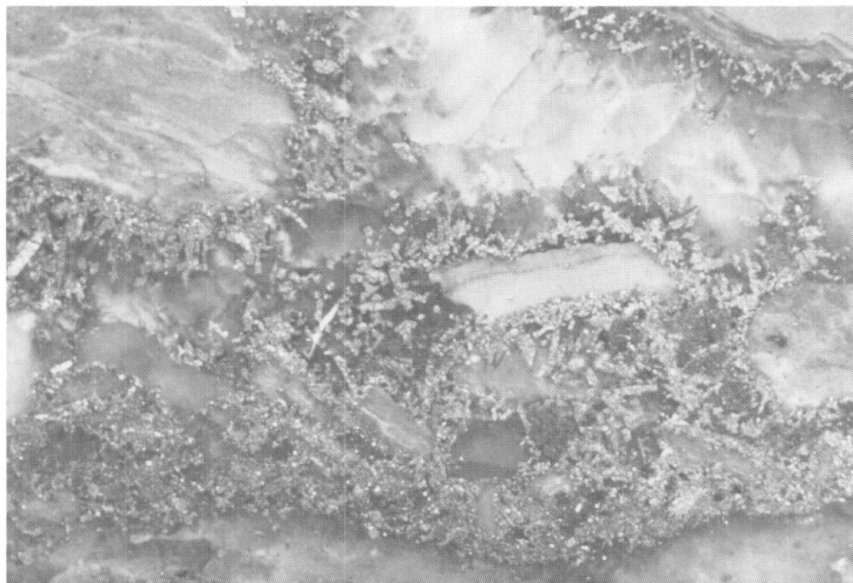


Figure 10. Arsenopyrite partially replacing silicified and brecciated siltite and being replaced by early quartz; Conjecture Mine.

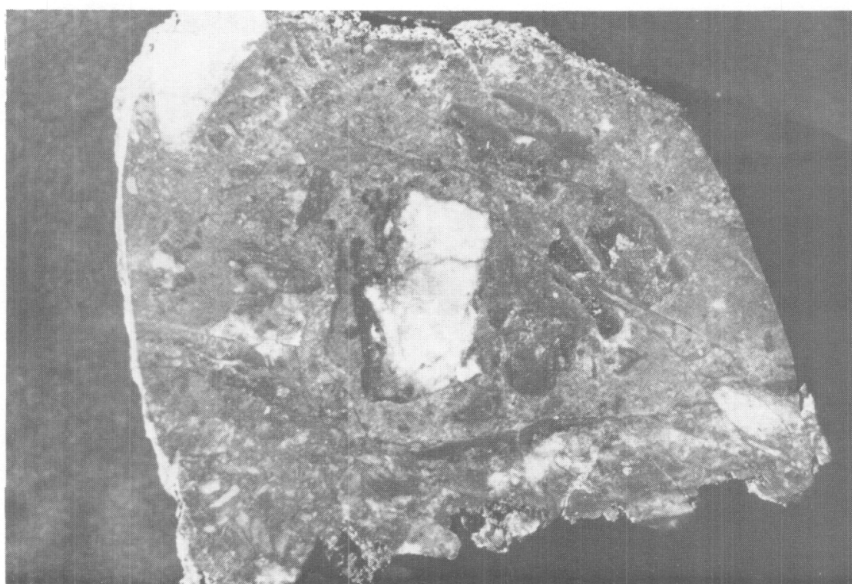


Figure 11. Breccia of early quartz partially replaced by galena and tetrahedrite; Vulcan Mine.



Figure 9. Polished section of the ore from the Conjecture Mine. (2 x actual size).

Explanation: SL = silicified limestone; Asp = arsenopyrite; EQ = early quartz; EP = early pyrite; Ga = galena; Tt = tetrahedrite; Stb = stibnite; RS = ruby silver; LP = late pyrite; LQ = late quartz.

Rhodochrosite and Siderite. Perhaps the major difference between the mineralogy of the Coeur d'Alene, and Clark Fork, and the Lakeview mining districts, is that although siderite is the dominant carbonate at Coeur d'Alene and Clark Fork, rhodochrosite and siderite are equally abundant at Lakeview. Rhodochrosite is almost absent in the Coeur d'Alene and Clark Fork mines (Anderson, 1930; Fryklund, 1964), while it is as abundant as siderite in some samples from Lakeview.

Rhodochrosite (MnCO_3) and siderite (FeCO_3) displaying colloform banding and sometimes cockade texture (Edwards, 1947, p. 19), form fracture-filled veins of about 5 mm. to 10 mm. in width which engulf angular host-rock fragments. Rhodochrosite is more abundant in specimens from the Conjecture Mine than in others from the district, but rhodochrosite-filled vugs and fractures have been reported from the Weber Mine (private report, 1926), and minor rhodochrosite can be seen in specimens from the Vulcan and Keep Cool mines. The mineral is usually very light pink under polarized light, shows polysynthetic twinning, with rhombohedral crystal outline. In hand specimen, siderite is pale brown to cream, forming similar fracture-filled veinlets as rhodo-chrosite (Fig. 12). Siderite is usually a very light gray under polarized light, with no visible crystal outline. Sampson (1928) reports that the presence of rhodochrosite and siderite is an excellent indication of high-grade ore in the Lakeview district.

Sphalerite. Varying amounts of sphalerite ($[\text{Zn}, \text{Fe}] \text{S}$) are present in most mines of the Lakeview mining district. Mines at which sphalerite has not been found are the Conjecture and Vulcan mines, and the Glasscock adits north of Lakeview.

Most sphalerite is very fine grained, dark brown to black, massive and anhedral, and in most specimens, visible to the naked eye (Fig. 13). The streak is usually a yellow-brown. The sphalerite grains are often surrounded by other sulfides, usually galena, and sometimes replace the carbonates. Sphalerite often has pyrite inclusions, suggesting that the pyrite is being replaced.

Personal observations and examination of the mine maps show that sphalerite is relatively abundant, while tetrahedrite is scarce in the upper levels of the Weber and Idaho Lakeview mines. Ore specimens from the deepest workings in the district, the 2,000 ft. level of the Conjecture Mine, have tetrahedrite but no visible sphalerite (Fig. 12). This observation conflicts with Anderson's (1947) report of sphalerite increasing with depth in the Clark Fork district, 32 miles to the north of Lakeview.

The sphalerite appears to be older than the galena because it is commonly enclosed and penetrated by galena. It has been deposited in openings, and it penetrates and replaces carbonates and pyrite, forming massive ores. Younger tetrahedrite also penetrates galena and sphalerite and in some specimens even replaces these minerals.

Galena. Galena (PbS) is the most abundant ore mineral, and the source of most of the lead and silver produced in the Lakeview mining district.

The mineral is medium to fine grained and usually massive. Little of it is euhedral. Most galena grains are less than 5 mm. in diameter, although some crystals of over 1 cm. on edges can still be seen in the Glasscock mines ($\text{S}_{\frac{1}{2}}$, sec. 35, T. 54 N. R. 1W). In contrast to the galena from most of the mines in the Coeur d'Alenes, little schistose or steel galena, formed by postmineral fault movement, has been found in the Lakeview district.

Most massive galena contains varying amounts of country rock and doubly terminated quartz crystals. Galena appears to be one of the youngest of the early ore minerals. Micrographic intergrowths indicate that, in some instances, galena is almost contemporaneous with tetrahedrite (Fig. 14). The mineral partially or completely replaces brecciated grains of wallrock or massive quartz (Fig. 11), and sometimes forms crustifications (Fig. 15). Galena veinlets penetrate earlier minerals (Fig. 12), this being especially noticeable between grain boundaries and along contacts between quartz veins and older minerals.

Tetrahedrite. Tetrahedrite (Cu, Fe, Zn, Ag)₁₂ (Sb, As)₄ S_{13} is the third most abundant ore mineral after galena and sphalerite. It is the principal silver-bearing mineral in the Coeur d'Alene mining district (Fryklund, 1964), but is much scarcer in Lakeview.

The tetrahedrite forms masses of anhedral grains which occupy fractures between early pyrite and galena. In some cases, tetrahedrite penetrates older sulfides and quartz through fractures, and in others, engulfs them partially or completely. Micrographic intergrowth of galena and tetrahedrite can be seen in several samples (Fig. 14). An exsolution texture of pyrite in tetrahedrite can be seen in specimens from the deep level of the Conjecture Mine.

Tetrahedrite is abundant in samples from the deeper levels of the Conjecture Mine, while sphalerite is absent and galena is present only in smaller amounts.

Second Stage Minerals

Massive and drusy quartz is the most widespread and characteristic mineral of the second-stage mineralization at Lakeview. Second stage sulfosalts are present in the deeper levels of the Conjecture Mine (Pl. 4), and boulangerite (?) has been identified in two samples from the same mine. Boulangerite (?) ($\text{Pb}_5\text{Sb}_4\text{S}_{11}$) forms rims around small tetrahedrite grains and is interstitial in galena and quartz. The second stage sulfosalts differ from tetrahedrite in grain size, crystal outline, and fracture-filling position. Pyrargyrite (Ag_3SbS_3) and native silver have been reportedly found in the 2,000 ft. level of the Conjecture Mine (Pl. 4). Stibnite (Sb_2S_3) was identified by microscope studies in two specimens from the Conjecture Mine. The mineral forms 6 mm-long blades in and around tetrahedrite and early quartz.

Chalcopyrite (CuFeS_2) is present in specimens from the Keep Cool Mine and Copper Queen mines. In the Keep Cool Mine, chalcopyrite forms anhedral masses of about 5 mm in diameter, surrounded by tetrahedrite, galena, and quartz. The mineral is not abundant. In the Copper Queen Mine it is present together with late pyrite in massive quartz veins.

Pyrite of very different physical characteristics from the early pyrite has been identified in this study. Second stage pyrite has been found in specimens from all the mines as untarnished euhedral crystals on the boundaries between the late, drusy quartz and older sulfides, or wallrock. This pyrite contrasts with the early pyrite which is usually very fine-grained or colloform.

Some crosscuts on the main level of the Idaho Lakeview Mine pass through 30-foot wide veins of massive, vitreous quartz. Massive quartz boulders of over 10 ft. on a side are found along the surface trace of the Conjecture vein. Drusy quartz, exhibiting fracture-filling textures, and usually barren of sulfides or other minerals, is found in all the mines. Where inclusions occur, they consist of small masses of sulfides or altered country rock.

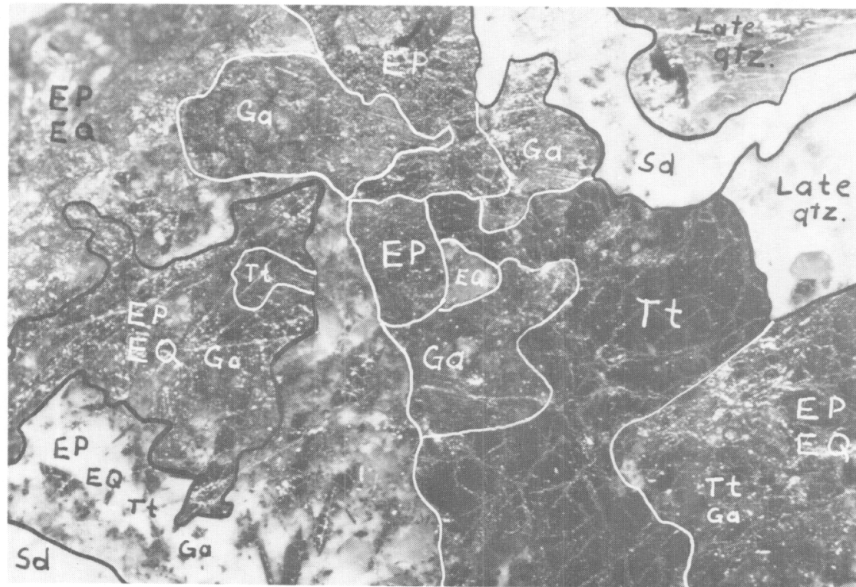


Figure 12. Tetrahedrite (Tt), galena (Ga), early pyrite, (EP), early quartz (EQ), and siderite (Sd), in typical texture of high grade ore. Conjecture Mine, 2,000 ft. level.

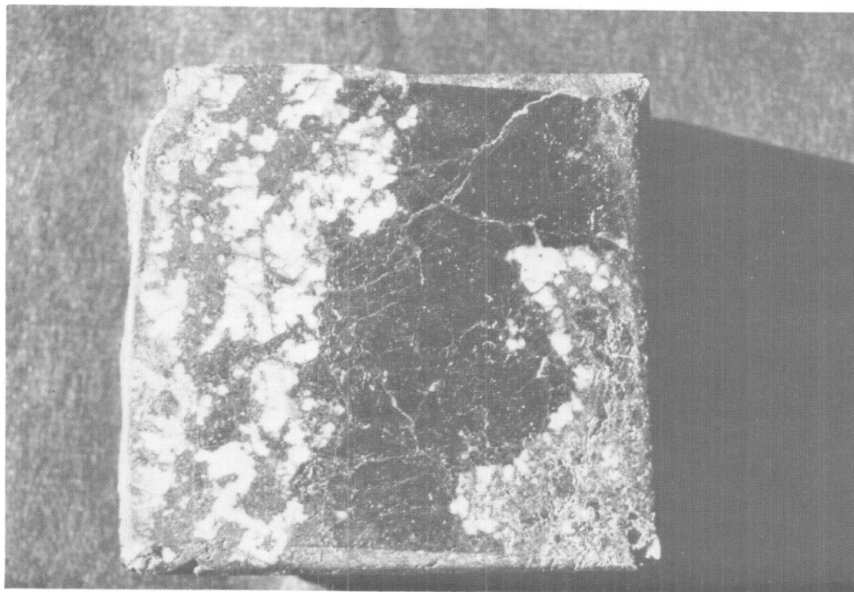


Figure 13. Massive sphalerite partially replacing early quartz. Galena and tetrahedrite filling fractures in quartz. Keep Cool Mine.



0.25 mm

Figure 14. Micrographic intergrowth of galena and tetrahedrite 2,000 ft. level, Conjecture Mine.



Figure 15. Crustification of galena and quartz in typical fracture-filling texture. Conjecture Mine. Actual size.

The second stage minerals probably represent the last period of mineralization in the district. They were deposited contemporaneously or a little later than mafic dikes and were associated with a reopening of the shear zones. The presence of primary sulfosalts at depth in the Conjecture Mine, and their almost total absence from the higher levels in the district, would suggest that second stage mineralization (with the exception of quartz) occurs only at depth.

Anderson (1947) estimated that one-fourth of the ores in the Hope mine, the largest mine in the Clark Fork district (Fig. 1), originated as a second-stage hypogene event. In the same district, ore with second-stage hypogene enrichment, is 10 to 20 times higher in silver content than the unenriched ore (Anderson, 1947). Also, the unenriched ore contains only 0.1 to 0.3 percent antimony, whereas the enriched ore contains 1 to 2.3 percent. Concentrates from the enriched ore contain 1 to 4 percent antimony in the upper levels of the mine, and as much as 9.6 percent in the lower levels. In the Lakeview district, as seen in the accessible workings, this stage is represented primarily by massive, drusy quartz. Silver-bearing sulfides appear to increase with depth, and further exploration may prove that, similar to the ores in the Clark Fork district, substantial enrichment exists at depth.

Supergene Minerals

The Glasscock adits ($SE\frac{1}{4}$, sec. 35, T. 54 N., R. 1 W.), are the only accessible mines in the Lakeview district where supergene minerals with gossan textures can be recognized. Galena (PbS) is being replaced by anglesite ($PbSO_4$) and cerussite ($PbCO_3$). Cleavage boxwork (Blanchard, 1968) formed by silica depositing along cleavage fractures in galena and thus withstanding weathering, as opposed to the galena, is visible. Banding of anglesite is prominent, whereas cerussite is found in narrow veinlets.

Supergene enrichment was of economic importance in some of the undeveloped veins in the Lakeview mining district. Many of the former gossans were probably eroded during Pleistocene glaciation, and because of the massive character of most of the orebodies, post-glaciation oxidation of the sulfides is only partial, and occurs at shallow depths. Supergene enrichment was probably responsible for the high grade ore (150-200 oz/ton silver) mined from the upper levels of the Conjecture, Weber and Idaho Lakeview mines in the early days of the district.

Quartz veins in the Paleozoic sediments show "gossan" textures. No sulfides were found in any of the outcrops but coarse cellular boxwork derived from pyrite and galena can be seen. Crystalline and drusy quartz make up the bulk of the specimens, with goethite and hematite coating fractures. According to Blanchard (1968, p. 90), both goethite and this type of hematite (called supergene hematite) are indigenous or transported limonites derived from galena and sphalerite.

Paragenesis

The order of mineral succession has been partially included in the description of individual minerals. Only a summary of the paragenesis of the ores as related to tectonic events is presented in this section (Fig. 16).

The first stage of metallization is well defined and the textures indicate that the paragenetic sequence is similar throughout the district. The first minerals of

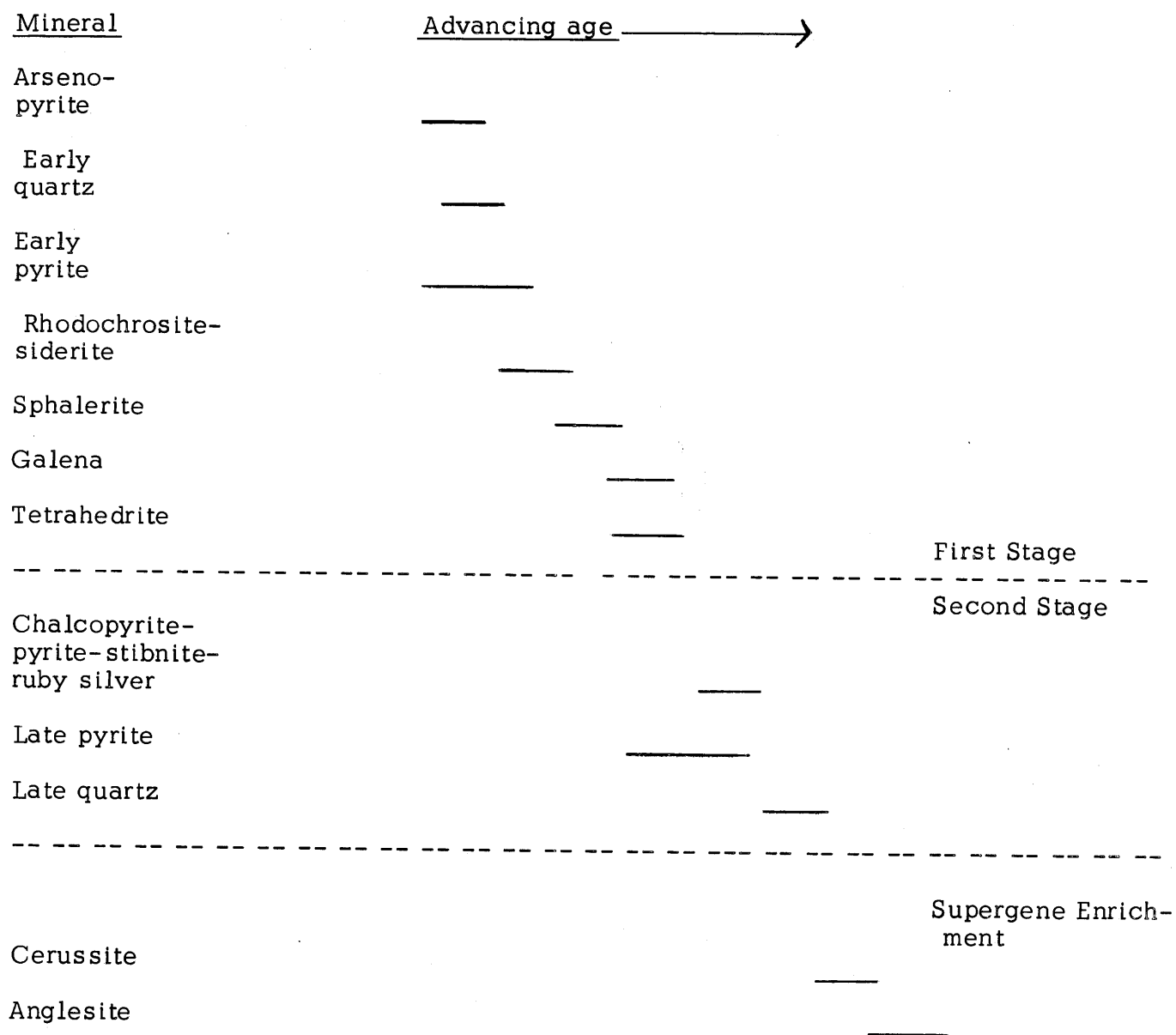


Figure 16. Generalized mineral paragenesis of the ores from Lakeview mining district.

importance to be deposited were early quartz and pyrite. Pervasive silicification is noticeable around the fractures and shear zones, and small pyrite cubes appear to be more abundant in the country rock (especially the calcareous beds) around the same structures. Breccia fragments in the shear zones are silicified and contain much finely-crystalline pyrite. The quartz, in turn, is brecciated, indicating tectonic activity prior to the deposition of the next generation of minerals. Quartz and pyrite were followed by fracture filling by carbonates. Siderite and rhodochrosite filled existing fractures, and partially replaced and engulfed older breccia fragments.

Sphalerite was the first major ore sulfide to be deposited. Galena and tetrahedrite apparently followed sphalerite. Galena is believed to have preceded tetrahedrite and is the first sulfide that shows evidence of partially or totally replacing the older minerals. Galena and tetrahedrite were probably deposited during a short interval of time, almost contemporaneously, because in certain specimens galena definitely appears younger than tetrahedrite.

The second-stage hypogene mineralization was preceded by intense shattering along the shear zones, probably accompanied by the introduction of mafic dikes in the pre-existing fractures. Much of the first-stage ore was brecciated at the same time. Renewed mineralization began with the introduction of hydrothermal solutions which partially altered and replaced the older sulfides, and formed sulfosalts. Chalcopyrite and pyrite were deposited at this time. Deposition of massive quartz veins marked the end of this stage of mineralization. Oxidation, leaching, and some supergene enrichment followed the emplacement of the first two stages and affected the near-surface extensions of most orebodies.

Recent potassium-argon dating of the Kaniksu Batholith in northeastern Washington (Yates and Engels, 1968) has yielded ages of 92.2 ± 3.0 m.y. on biotite from quartz monzonite samples. Previous work (Jaffe and others, 1959) on zircon from granodiorite of the Colville Batholith, about 30 miles to the south, yielded a lead-alpha date of 99 ± 10 m.y. Because I believe the Lakeview ore deposits to be genetically related to the granodiorite stocks in the area, the age of first mineralization would appear to be about 95 m.y. Yates and Engels (1968) dated hornblende from lamprophyre dikes in the Kaniksu Batholith at 51.7 ± 1.5 m.y. If the lamprophyre dikes in Lakeview are genetically related to the second hypogene stage of mineralization, this event could have occurred in early Eocene time. It is possible that the ore deposits were affected by cataclastic metamorphism as recently as 11 ± 1 m.y., which is the age of the last metamorphic deformation of the Valhalla Complex in British Columbia (Lowdon, 1961).

Description of the Mines

Conjecture Mine

The Conjecture Mine is located 6 miles south of Lakeview on Gold Creek ($N\frac{1}{2}$, sec. 26, T. 53 N., R. 1 W) (Fig. 2). Located in 1894, the Spider and Graham adits produced high grade ore until the early 1920's, when the inclined shaft was started. The incline replaced a vertical shaft that had been damaged by fire (Sampson, 1928). Lakeview Silver Mines Co. operated the mine intermittently from the 1920's until early 1951 when the mine and adjacent patented claims were purchased by D.E. Majer and L.H. Funnel, who formed Conjecture Mines, Inc. This company mined ore from four levels using the inclined shaft until 1956 when Federal Resources Corporation leased the property in order to undertake an exploration program. By 1963, Federal

Resources had finished a 2,000 ft shaft, about 500 ft. northeast from the incline (Pl. 4), and had driven over 13,000 ft. of drifts from four levels. The results of this exploration work were not satisfactory to Federal Resources and the property was returned to Conjecture Mines, Inc. in 1965. In 1967, Duval Corporation leased all the property and conducted surface exploration including soil sampling and detailed mapping. Duval Corporation also initiated underground exploration by partially de-watering the vertical shaft and by core-drilling from the surface to a depth in excess of 4,000 feet. The property was once again returned to Conjecture Mines in 1970.

At the property, Gold Creek cuts through the middle part of the Lower Member of the Wallace Formation. Good exposures can be seen in roadcuts north and south of the mine. Most workings in the Conjecture Mine area, which are shown in Plate 4, are confined to the calcareous part of the Lower Member. The contact between the St. Regis and Wallace Formations is present between the 1,000 and 2,000 ft. levels in the new shaft. Part of the workings on the 2,000 ft. level are in the St. Regis Formation and specimens representative of this formation are present on the dump.

The Conjecture orebody consists of several ore shoots (Pl. 5) which apparently merge at depth to form two mineralized zones, which follow the trend of the Conjecture shear zone. The Conjecture shear zone (Pl. 1) trends approximately N. 30° E. and dips 65 degrees to the north. The north-south trending, normal, Spider fault offsets the shear zone, with the eastern block uplifted (Pl. 1 and 5). Unpublished assay plans indicate that the ore shoots are not homogeneous in sulfide content. In the upper levels of the inclined shaft, very high-grade ore, possibly supergene-enriched, was mined. In the deeper levels, the ore zones are restricted to vein-type fracture fillings, with erratic width and metal content. The veins often have a gradation into barren shear zones, or are partially displaced by lamprophyre dikes (2,000 ft. level on Pl. 4).

Open-space filling textures are characteristic of ore from the Conjecture Mine. Galena, tetrahedrite, rhodochrosite, arsenopyrite and quartz fill fractures in brecciated host rock, early quartz, or later second stage sulfides (Fig. 9). Early pyrite is found disseminated in the host rock and forming crustifications next to the vein walls. Arsenopyrite is engulfed by early quartz and is visible in fractures of brecciated siltite. Crustifications of galena and tetrahedrite are separated by drusy quartz with some stibnite crystals visible in fractures. The paragenesis of the Conjecture ores is shown on Figure 17. An interesting feature of the ores is the presence of rhodochrosite as gangue carbonate instead of siderite, and the lack of sphalerite in the ore. Pyrargyrite (?), native silver (?), and boulangerite (?) are reported to occur in several places on the 2,000 and 1,000 ft. levels (Pl. 4).

The total production from the Conjecture Mine, during the years 1952-1954, is summarized on Table 2. A total of over 360 tons of ore were shipped during this time to the Bunker Hill smelter near Kellogg, Idaho. The ore with the highest silver content was apparently mined from the 100 and 200 ft. levels, because it contained only 4 percent iron and 8 percent sulfur, as compared to 35 percent iron and 34 to 45 percent sulfur in other ore shipments. The ore probably was taken from the enriched zone where iron and sulfur had been leached out while the base metals had been concentrated. The silica content in the ore from the same origin is 38 percent, but is only 7 to 17 percent in later shipments. Zinc content has a range from 15 percent in the lower levels. Antimony and arsenic content of the ore remained constant in most assays. As can be seen from Table 1, the silver and base metal content of the Conjecture Mine production from 1952 to 1954 was high.

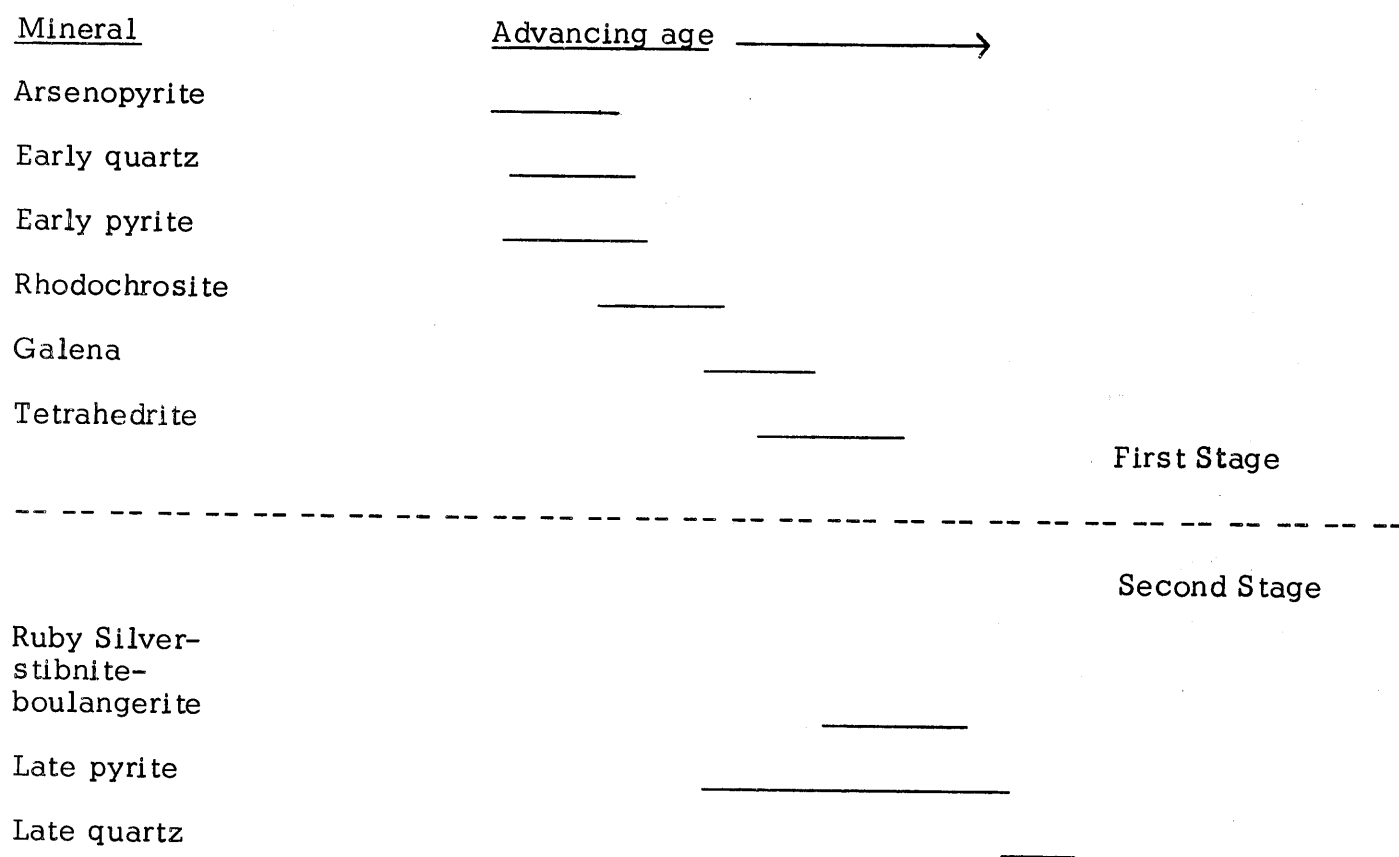


Figure 17. Mineral paragenesis of the ores from the Conjecture Mine.

Table 1. Weighted averages of production assays from the Conjecture Mine, 1952-1954.

Year and Production	Au, ox/ton	Ag, oz/ton	Pb%	Cu%	Sb%	As%
1952						
117,060 lbs.	0.145	186.8	6.8	0.94	0.9	1.3
1953						
212,970 lbs.	0.128	58.1	4.6	----	----	----
1954						
390,780 lbs.	0.135	76.2	3.9	----	----	----
Highest assay results	0.37	265.05	21.6	1.00	1.6	1.95
Lowest assay results	0.09	36.9	1.6	0.35	0.2	0.46

Assays: The Bunker Hill Co., Kellogg, Idaho.

Weber open-pit and Mine

The Weber open-pit and adjacent properties are on Gold Creek, one mile south of the Conjecture Mine (NW $\frac{1}{4}$, sec. 35, T. 53 N., R. 1 W.). This was the first mineral discovery in the district and was developed through four underground levels. The mine was initially worked by F.A. Weber, and after World War II leased under the name "New Rainbow Mine". In the late 1940's, an open pit mine was started above the old Weber Mine and has been worked intermittently since that time.

The open pit and mine (Pl. 6) are in the calcareous beds of the Lower Member of the Wallace Formation. The orebody is located to the west and adjacent to the intersection of the Weber vein and the Spider fault (Fig. 2), where the shear zone widens and is mineralized throughout the four levels of the mine (Pl. 6). Lamprophyre dikes cut through the orebody and late quartz veins were abundant enough in the mined portion of the pit to be shipped for their silica content to Tacoma, Washington (C. Weber, oral communication, 1967).

The underground workings are inaccessible because of caving, 400 ft. from the portal. No ore samples could be studied from the old Weber Mine because they were not available and only strongly weathered specimens could be found on the dumps. The ore is brecciated in the open pit and consists mainly of galena, and minor tetrahedrite and sphalerite, with quartz as gangue (Fig. 18). The sulfides fill fractures and engulf early-stage quartz. Some ore is in massive crustifications having cores of late, drusy quartz. The Weber pit is on the Weber shear close to its intersection with the Spider fault. Quartz and sulfide veins within the shear zone can be seen in the upper benches, while lamprophyre dikes are visible in the bottom of the pit. An interesting characteristic of the open pit is the mineralization of the lamprophyre dikes. The mafic dikes, believed to be associated with the Spider fault, contain abundant disseminated pyrite and other unidentified sulfides.

Assays from smelter returns (Table 2), during the first few years of production show that since 1890, several shipments of ore were made with an average silver content of about 40 oz/ton, 8-10 percent lead and an equal percentage of zinc. Savage (1967) reports that the ore shipped in 1962 to the Tacoma, Washington, smelter contained about 0.04 oz/ton of gold, 7 to 8 oz/ton of silver, and 0.5 percent of combined lead and zinc. The production and average grade (Table 2) for the years 1890 to 1934 are from the underground workings, while the 1963 figures are from the open pit where quartz was the main mineral mined and the ore was 60-80 percent silica.

Idaho Lakeview Mine

The Idaho Lakeview Mine is in Chloride Gulch, about 5 miles south of Lakeview (NW $\frac{1}{4}$, sec. 28, T. 53 N., R. 1 W.). The main level is open, but examination of many openings was hindered by poor ventilation. The mine, since its discovery in 1926, was one of the most productive in the Lakeview district, but it has not operated since 1959. In 1967, Sunshine Mining Co. leased the property and conducted bulldozer trenching and geologic mapping.

The Idaho Lakeview Mine is located entirely in the siltites and argillites of the Middle Member of the Wallace Formation. The geology of the lower levels, which are driven from an inclined internal shaft, is not known, except for the information presented on Plate 3. The orebody is contained within the Hower shear and appears to be

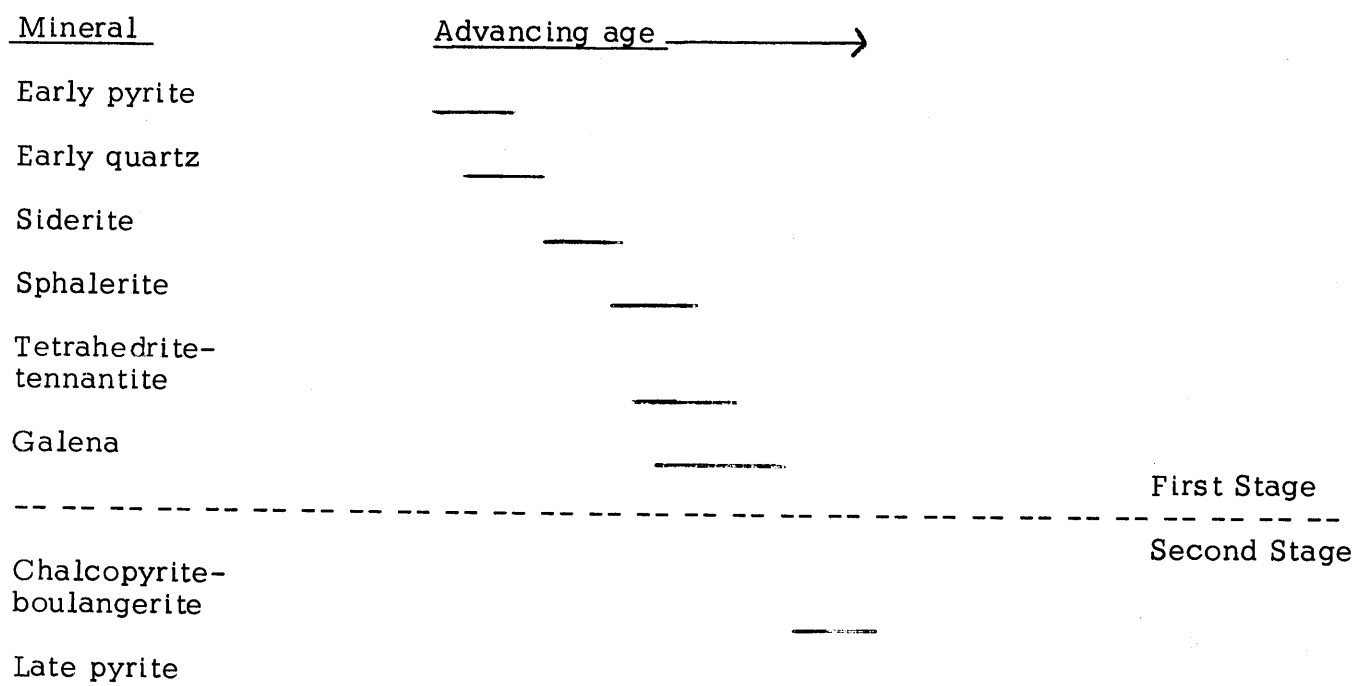


Figure 18. Mineral paragenesis of the ores from the Weber open pit mine.

Table 2. Assays from the Weber Mine and open pit, 1890-1963.

Date	Tons	Ag oz/ton	Au oz/ton	Pb%	Zn%	Sb%	As%
1890	280	40	----	8-10	8-10	----	----
1896	2200	27	----	----	----	----	----
1896- 1900	100	24-33	----	----	----	----	----
1901	960	30.5	----	----	----	----	----
1907- 1908	15	160	----	----	----	----	----
1934	----	40-105	0.10	3-4	12	1.0	1.0
1963	----	4.2-16.5	0.03	----	----	----	----

similar to the Conjecture Mine, with massive ore shoots, separated by very low grade sulfide zones. Stopes more than 100 ft. in height indicate that the shoots were continuous for a considerable distance in the dip direction.

Ore specimens found on the Idaho Lakeview dumps have massive sulfides including blebs of pyrite, galena, and tetrahedrite (Fig. 19). Exsolution of pyrite from tetrahedrite along cleavage planes can be observed in one specimen. Replacement textures between galena and tetrahedrite are characteristic of these specimens more than elsewhere in the district. Another characteristic is that large zones of late quartz occupy as much as half of the width of the Hewer shear.

Examination of smelter returns obtained on shipments made in 1935-36 show that the ore contained about 12 to 15 oz/ton silver, and 2 percent lead and 2 percent zinc. This ore originated from the main and 100 ft. levels, and was mostly oxidized.

Keep Cool Mine

The Keep Cool Mine is located about 5.5 miles south of Lakeview on the East Branch of Chloride Gulch in SE $\frac{1}{4}$, sec. 27, T. 53 N., R. 1 W (Pl. 1). Mine workings (Fig. 20) in 1928 included five adits driven as drifts (Savage, 1967). In 1937, the lower (no. 5) level was used as main haulage level, and ore from the mine was being milled in the adjacent mill and shipped by truck to the Bunker Hill smelter (Kotschevar, D.D., 1938). In 1967, the number 5 level was being reopened by the Sunshine Mining Co. who had leased the property. Few ore specimens and little geology could be seen because the drift was timbered throughout.

The Keep Cool Mine is entirely within the Lower Member of the Wallace Formation. The workings follow a vein on the western end of the Weber shear zone, and to the east of a barren, normal fault, which is similar in characteristics to the Spider fault (Fig. 2). Thus, the Keep Cool orebody appears similar to the Weber, in structure as well as texture and ore grade.

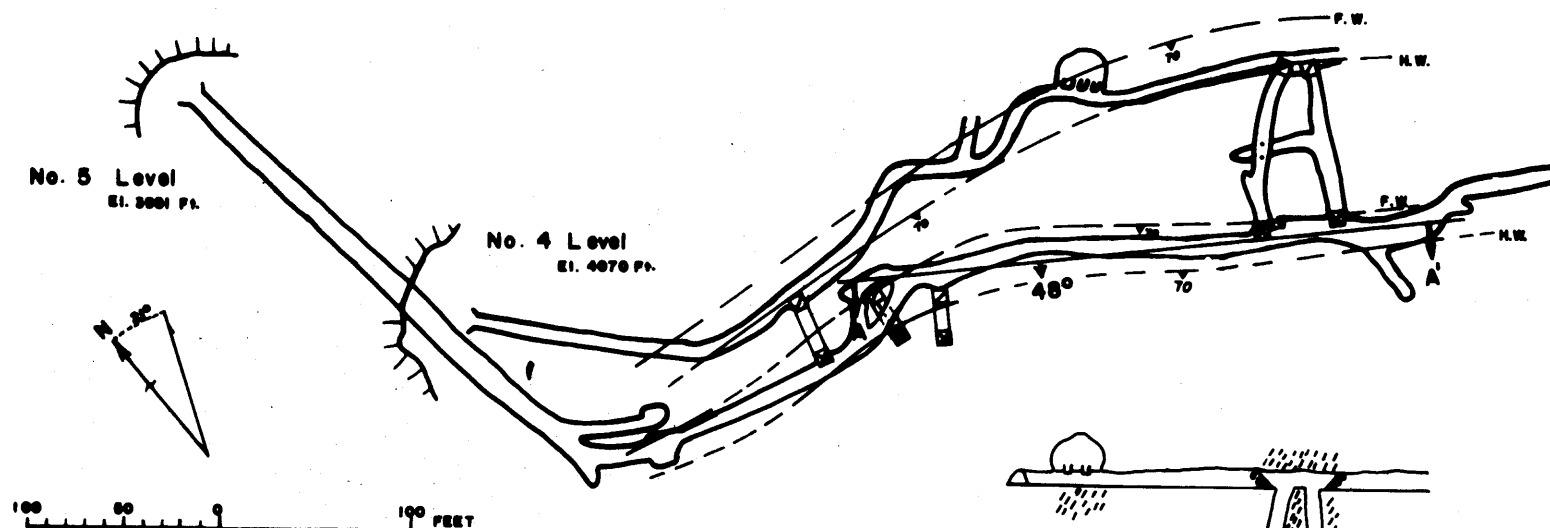
The ore specimens examined in this study were taken from the dumps. The samples show massive sulfides forming blebs in fractures (Fig. 13). The sulfides identified are galena, sphalerite and tetrahedrite, with minor chalcopryrite and boulangierite (?). Gangue minerals are pyrite, quartz and siderite. Kotschevar (1938) reports the ore as being:

"...galena, mainly as specular with gneissic grain and highly veneered surface. Sphalerite is intimately associated with galena. Chalcopryrite and pyrite are disseminated throughout the galena, sphalerite and quartz.."

The paragenesis of the ore minerals is shown on Figure 21. Assays from the two levels and stopes, shown on Figure 20, average 20 oz/ton in silver 3-4 percent lead and 6-7 percent zinc. No production data is available.

The Glasscock Properties

North of Lakeview (S $\frac{1}{2}$, sec. 35, T. 54 N., R. 1 W) about three miles up the main road, R. Glasscock of Lakeview has developed several small, high-grade ore shoots along a vein on what is locally called, Vulcan Hill. The development consists of about five adits driven along the vein, which cuts the Lakeview Limestone (Pl. 1), granodiorite, and siltites and argillites of the Wallace Formation. The limestone is



EXPLANATION

-  Ore
-  Caved workings.
-  Shear zone with dip (includes ore veins)
- F.W. Foot wall of shear zone
- H.W. Hanging wall of shear zone

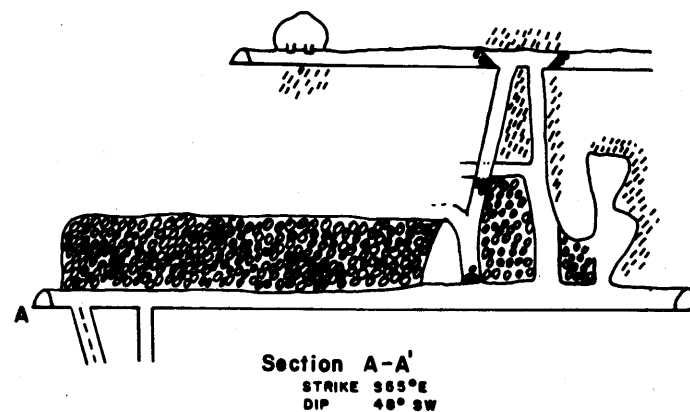


Figure 20. Plan and cross-section maps of the Keep Cool Mine.

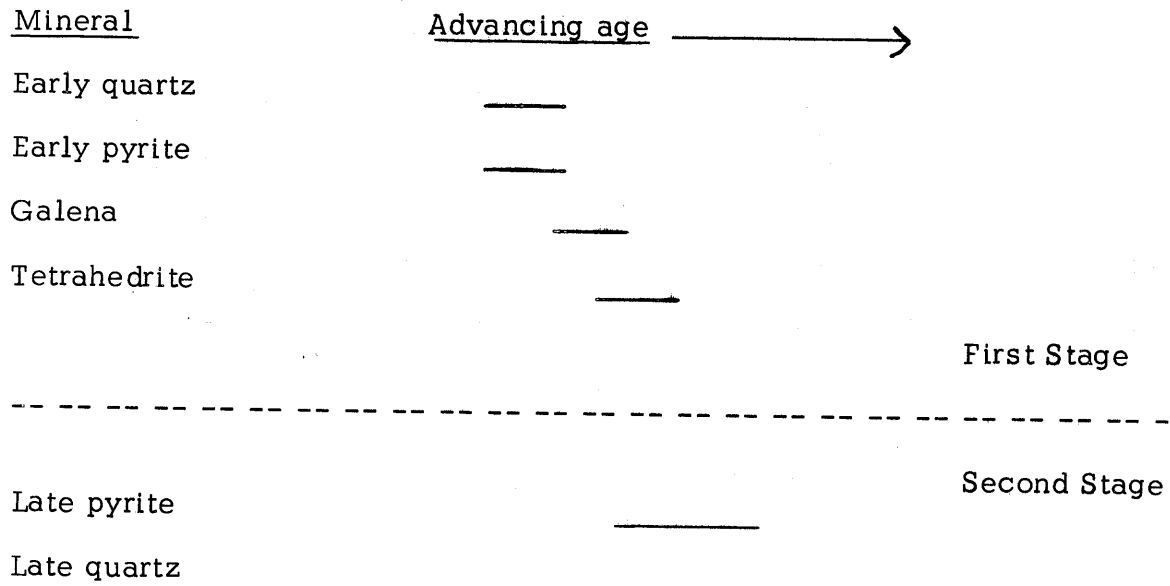


Figure 19. Mineral paragenesis of the ores from the Idaho Lakeview Mine.

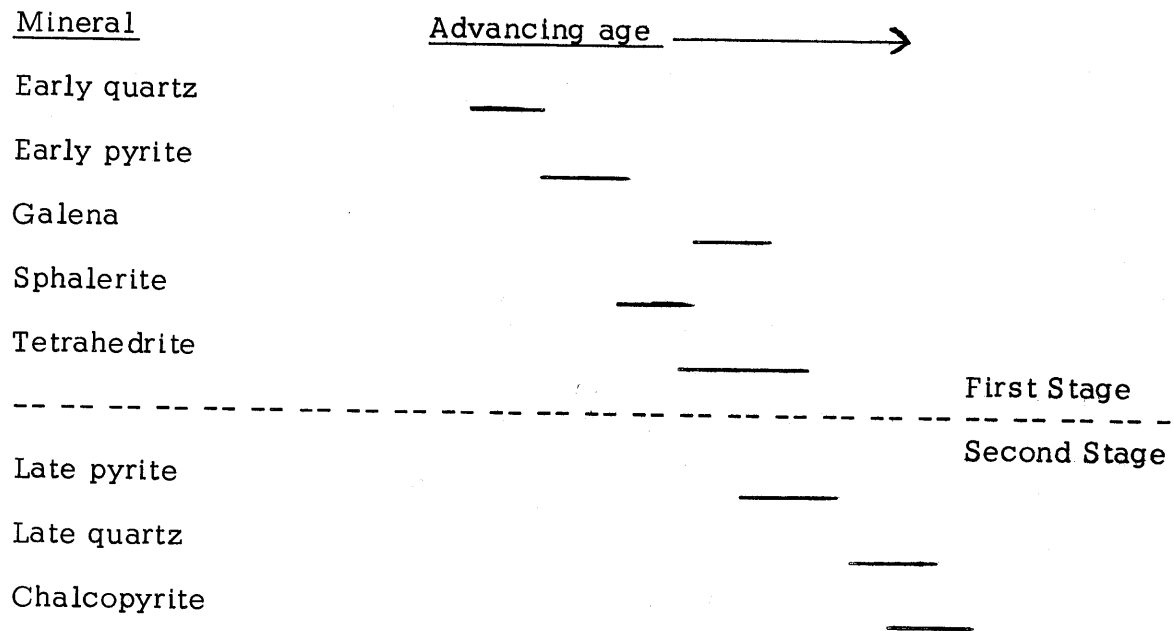


Figure 21. Paragenesis of the minerals of the Keep Cool Mine.

highly contact-metamorphosed in certain zones and is altered to a green hornfels or a white marble. The east-trending vein is filled with quartz, and galena, pyrite and tetrahedrite stringers, some of which form pockets rich enough to mine. Brecciation, fracture-filling and replacement textures can be noted in the ore specimens from the Vulcan Mine (Fig. 11). The main ore mineral is galena (Fig. 22), which forms massive blebs and replaces early quartz and pyrite. It is surrounded and partially replaced by tetrahedrite penetrating fractures. Late pyrite and quartz fill fractures, but are seldom seen replacing the older minerals.

The Vulcan Mine portal had caved by 1967, but some ore from it and the other Glasscock properties had been shipped to the Conjecture mill (Glasscock, oral communication, 1967). No assay or production statistics are available from any of the mines.

Other Mines

The Silver Leaf Mine is located on the east branch of Gold Creek in $SE\frac{1}{4}$, sec. 24, T. 53 N., R. 1 W., and is about eight miles southeast of Lakeview. The mine is on the easterly extension of the Conjecture vein (Pl. 1 and 2). No record of production and assays are available, and the rocks on the dump contain few visible sulfides. The mine is located within chloritized siltites and argillites of the Middle Member of the Wallace Formation.

The Dixie Queen Mine, overlooking North Gold Creek in $E\frac{1}{2}$, sec. 5, T. 53 N., R. 1 E, is the only mine in the district at which chalcopryrite is the sole valuable sulfide mineral. Chalcopryrite is disseminated in a vitreous quartz vein as seen in specimens collected from the dump. All samples are oxidized. The mine portal is caved and no information about production or grade is available. The country rock is composed of argillites and siltites of the Middle Member of the Wallace Formation.

Several small adits on the lakeshore in $SE\frac{1}{4}$, sec. 34, T. 54 N, R. 1 W, have been worked for small, very rich pockets of silver ore. Some ruby silver and other sulfide minerals were found during the field work. The adits are in the Middle Member of the Wallace Formation and are possibly located on the western extension of the vein that is worked from the Glasscock properties (Pl. 1).

The Bellville adits ($NE\frac{1}{4}$, sec. 33, and $SW\frac{1}{4}$, sec. 27, T. 53 N, R. 1 W) are located in unaltered argillites and siltites of the Middle Member of the Wallace Formation. No specimens of sulfide minerals were found in the upper adit or dumps. The lower adit is caved at the portal and no information about production or grade could be obtained from the owner.

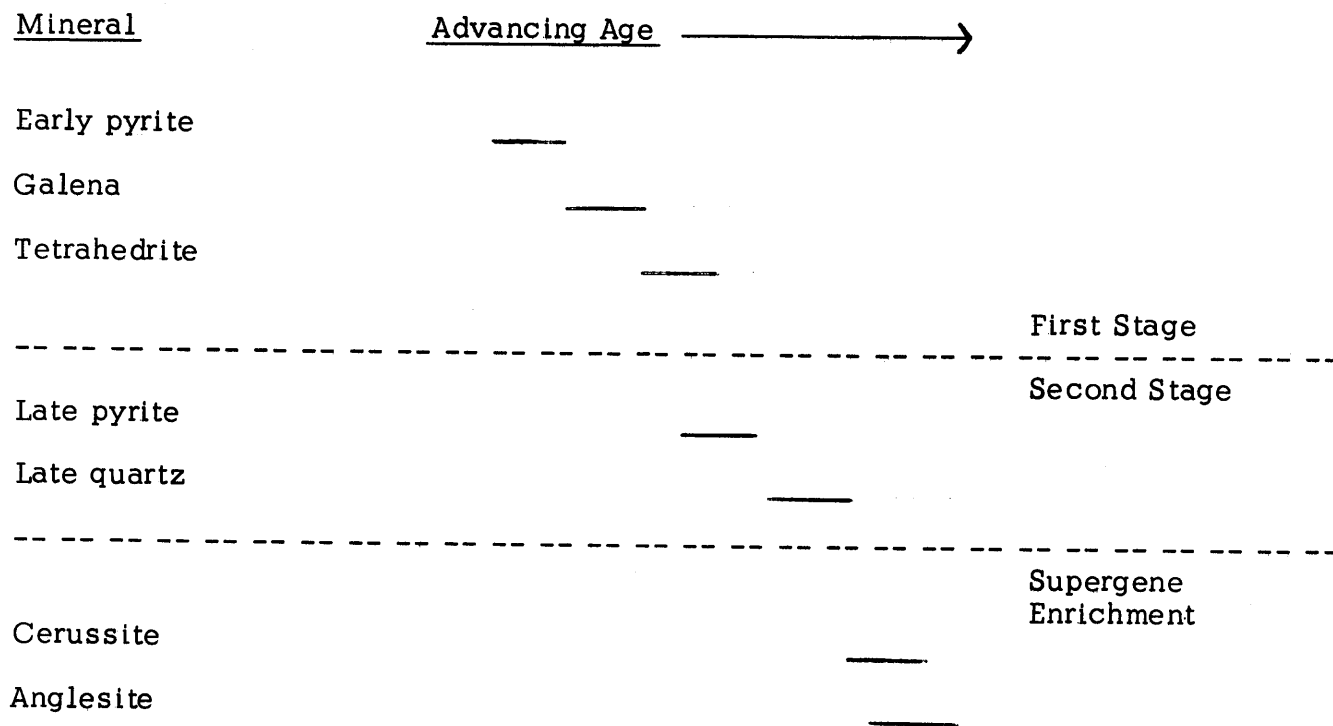


Figure 22. Mineral paragenesis of the ores from the Vulcan Mine and Glasscock adits.

CONCLUSIONS

The Lakeview mining district is situated on the margins of the Kaniksu Batholith. Most of the known orebodies are located within rocks of the Wallace Formation of the Belt Supergroup. Metallization occurs mainly in shear zones within the limestones, dolomites, siltites and argillites of the Lower and Middle Members of the Wallace Formation.

The orebodies are believed to be similar in age and genetically related to an underlying pluton. Results from an aeromagnetic survey in this region suggest that a granodiorite pluton at the northern part of the area plunges south under the metasediments and possibly underlies the central part of the district. Block faulting in the same area suggests a sequence of uplift and subsidence of blocks, with opening of fractures and emplacement of hydrothermally deposited minerals. These events are interpreted as being contemporaneous with the emplacement and cooling of the pluton. Assuming that the pluton is part of the Kaniksu Batholith, first-stage mineralization in Lakeview could have occurred about 95 million years ago. Second-stage mineralization may have been genetically related to the emplacement of lamprophyre dikes. Spessartite dikes, which in other parts of the world have been found to be associated with granitic plutons, are found in the Lakeview area intruding faults, cutting the orebodies, and containing sulfides. If the dikes are related to a younger granitic stock, their age may be about 51 million years. In this case, the Lakeview orebodies would be post-Laramide, younger than the Coeur d'Alene orebodies which are considered to be Late Cretaceous in age (Ridge, 1968, p. 1431).

Geologists working in the Coeur d'Alene district have concluded that the principal ore-controlling factor is the type of host rock. The St. Regis, Revett and Burke formations are the host rocks for the major productive mines. The calcareous parts of the Wallace Formation are considered as unfavorable stratigraphic horizons. The orebodies in the Lakeview district differ considerably from the Coeur d'Alenes, in that the ore shoots appear to be located on the intersections of shear zones with faults, rather than at stratigraphic horizons. Most of the ore extracted from the Lakeview mines originated in the calcareous beds of the Lower and Middle Members of the Wallace Formation. Ore grade and vein width appear to be constant with depth, without improving at the contact between the St. Regis and Revett formations, considered one of the most favorable stratigraphic horizons in the Coeur d'Alene district. The Conjecture vein has not shown the expected increase in ore grade and vein width close to the St. Regis-Revett contact, at the one mine where this contact is known. Further exploration at depth might, however, prove the existence of ore enriched by the second stage mineralization, as has been found in the Clark Fork mining district.

A marked increase in silver and base-metal content in the upper portions of all the mines is apparent from records of past production. Supergene enrichment is of much greater economic importance in Lakeview than has been previously recognized. Although the enriched portions of the known orebodies have been mostly mined out, large tonnages of moderate and low grade ore, perhaps amenable to a mass mining technique, may be found by further exploration work. Several outcrops of previously unreported oxidized veins were found during this study, and sample assays show these outcrops to have an equivalent metal content to outcrops above shear zones previously mined.

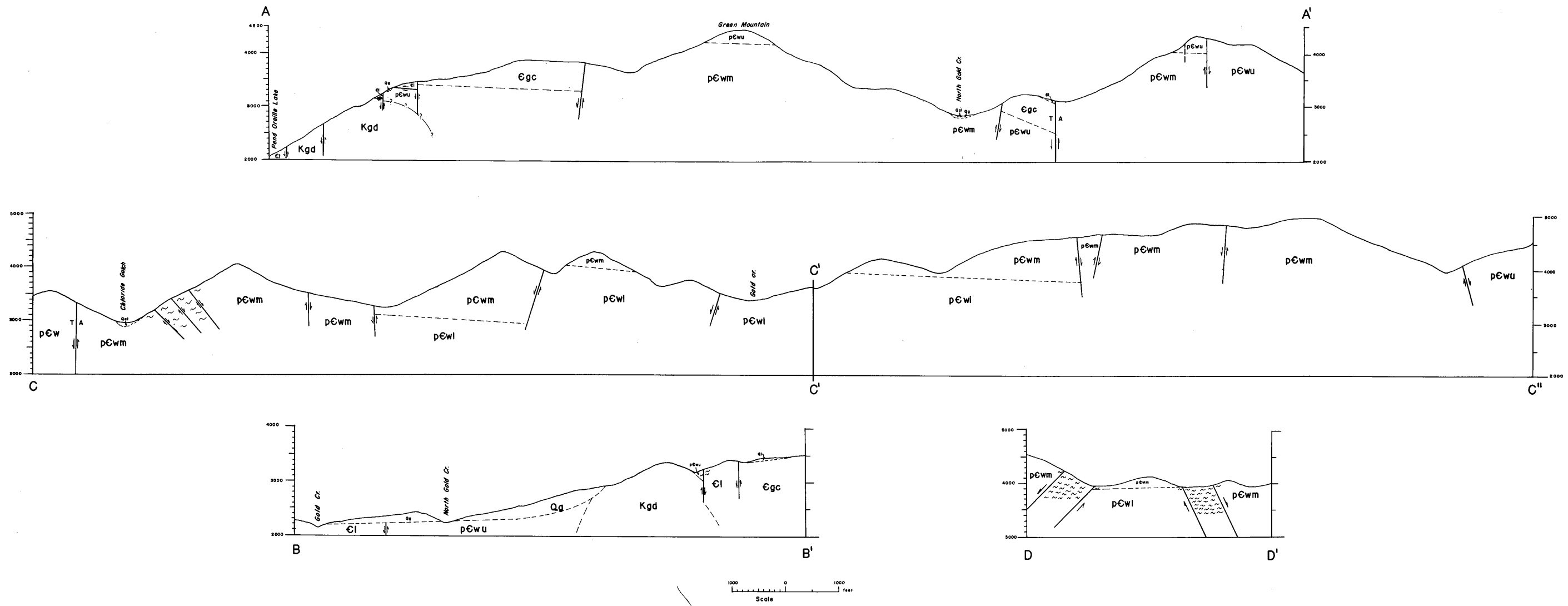
Ore mineralization in the Lakeview mining district appears to be restricted to an area bounded by the Packsaddle fault on the west and Cascade fault on the east. Ore occurrences outside these boundaries are very small in size and irregular in distribution. A possible exception to this distribution is in the northwest part of the mapped area, where there is a possibility of concealed contact metamorphosed deposits.

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CROSS-SECTIONS FROM PLATE 1

EXPLANATION

QUATERNARY

- Qal Alluvium
- Ql landslide deposits
- Qf talus deposits
- Qg Glacial deposits

UNCONFORMITY

- Cl Lakeview Limestone

Light gray to black, thin bedded limestone and dolomite, silty in places giving a mottled appearance. Metamorphosed in contact zones with granodiorite, changing to green and white, silty, about 2000 feet thick, is graded. A fissile, olive, massive shale not found in outcrop is reported to lie conformably between the Lakeview Limestone and the underlying Gold Creek Quartzite.

UNCONFORMITY

Belt Supergroup, Wallace Formation:

- pCwu Upper Member

Interbedded siltite, argillite and limestone mostly thin bedded, black, gray, and dark gray interlayers about 20 feet thick containing thin rock layers, are repeated throughout the Upper Member. About 2500 feet thick.

- pCwm Middle Member

Alternating thick argillite and thin siltite. Thin to thick bedded, slightly calcareous and dolomitic siltite. Some limestone beds in the upper part. About 3000 feet thick.

- pCwl Lower Member

Green gray dolomitic siltite, weathering rust brown, with boulders, ripple marks, fluting, etc.; dark gray and brown limestone weathering rusty brown, with stromatolites, dark, thin bedded to laminated argillite. Bucky weathering. About 2000 feet thick, bottom not exposed.

PRECAMBRIAN

Igneous Rocks:

- Kgd Granodiorite

Porphyritic granodiorite, purple and white when fresh, gray when weathered. Blackly weathering with rusty color on joint planes.

- Kl Mafic dikes

Lamprophyre dikes, dark green, slightly porphyritic. Diabase dikes reported from the Weber and Conjecture mines, not found in outcrops.

CRETACEOUS (?)

Contact

Dashed where approximately located, indefinite, or gradational; dotted where concealed.

Shear Zone

Includes quartz and sulphide veins, disseminated sulphides and quartz stringers; breccia and mylonite zones; lamprophyre dikes related to the shear zones.

Fault, showing dip and relative horizontal movement

Dashed where approximately located, short-dashed where inferred, queried where deduced from aerial photos and not checked on ground; dotted where concealed. U upthrown side, D downthrown side.

Landslide scar

Strike and dip of beds, horizontal beds.

Thrust Fault

Dashed where approximately located; dotted where concealed. Surface on upper plate.

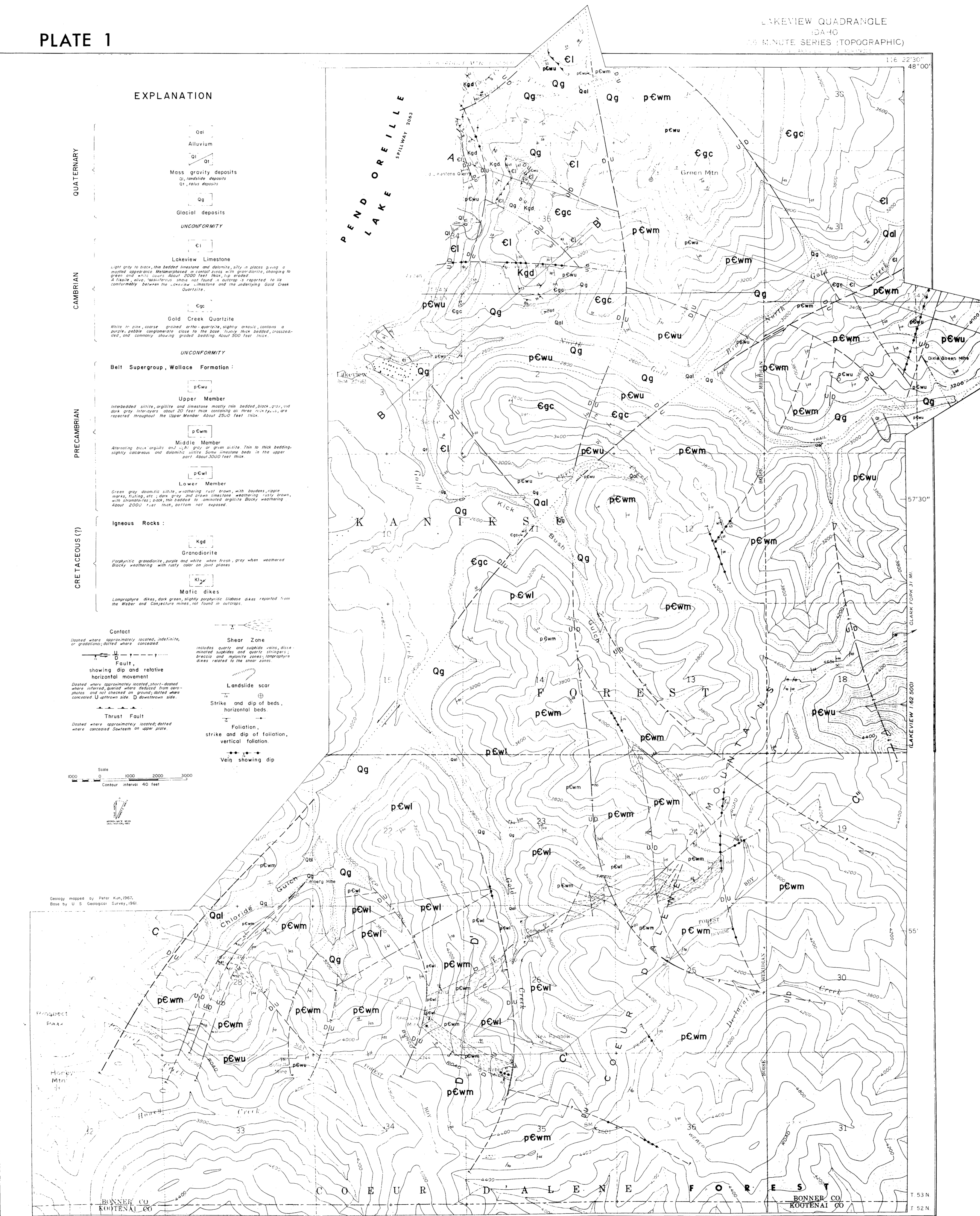
Foliation, strike and dip of foliation, vertical foliation.

Vein showing dip

Scale 0 1000 2000 3000
Contour interval 40 feet



Geology mapped by Peter Kun, 1967.
Base by U. S. Geological Survey, 1961

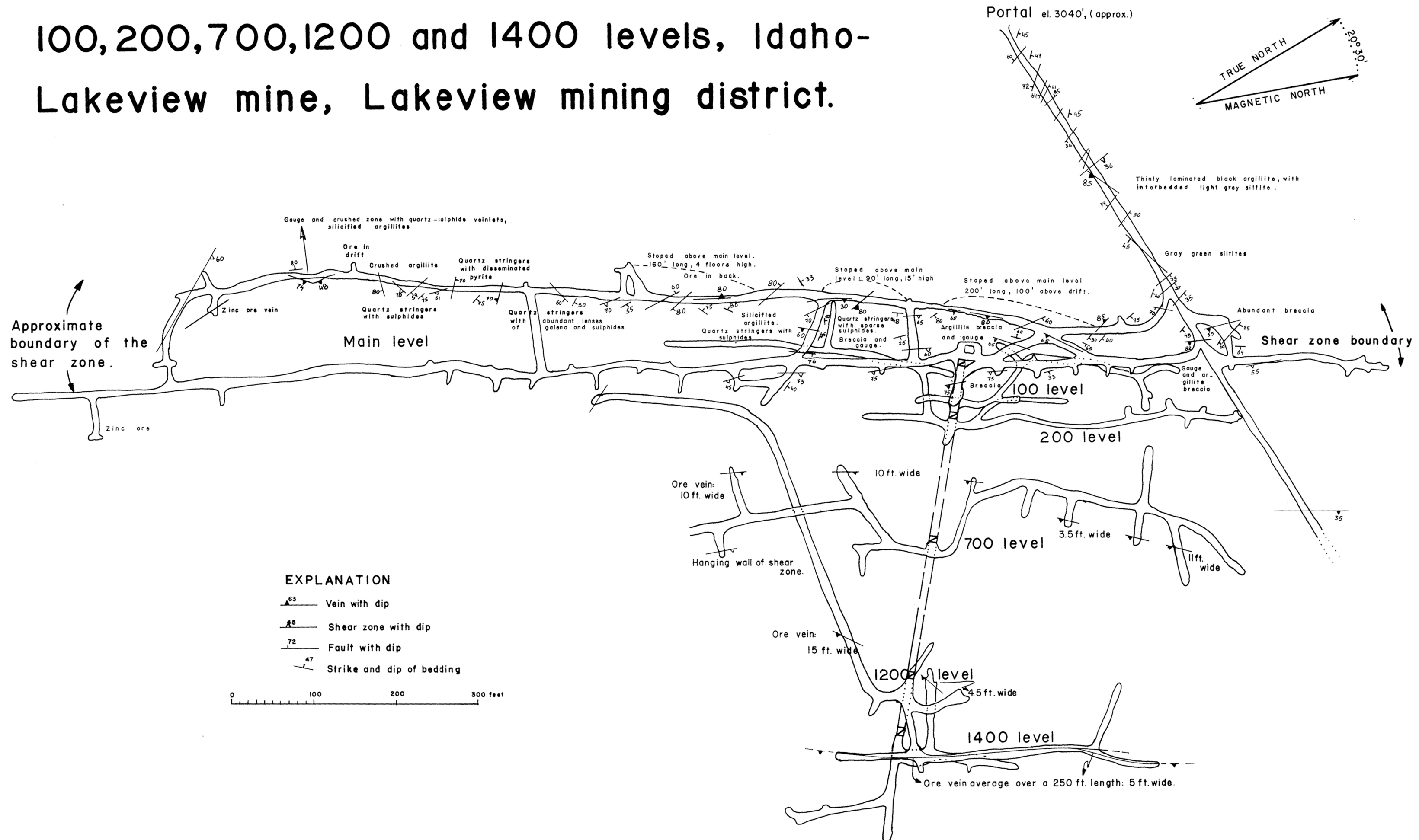


GEOLOGY OF THE LAKEVIEW MINING DISTRICT, IDAHO

By
Peter Kun

1969

Geologic mine and composite maps of the main, 100, 200, 700, 1200 and 1400 levels, Idaho-Lakeview mine, Lakeview mining district.

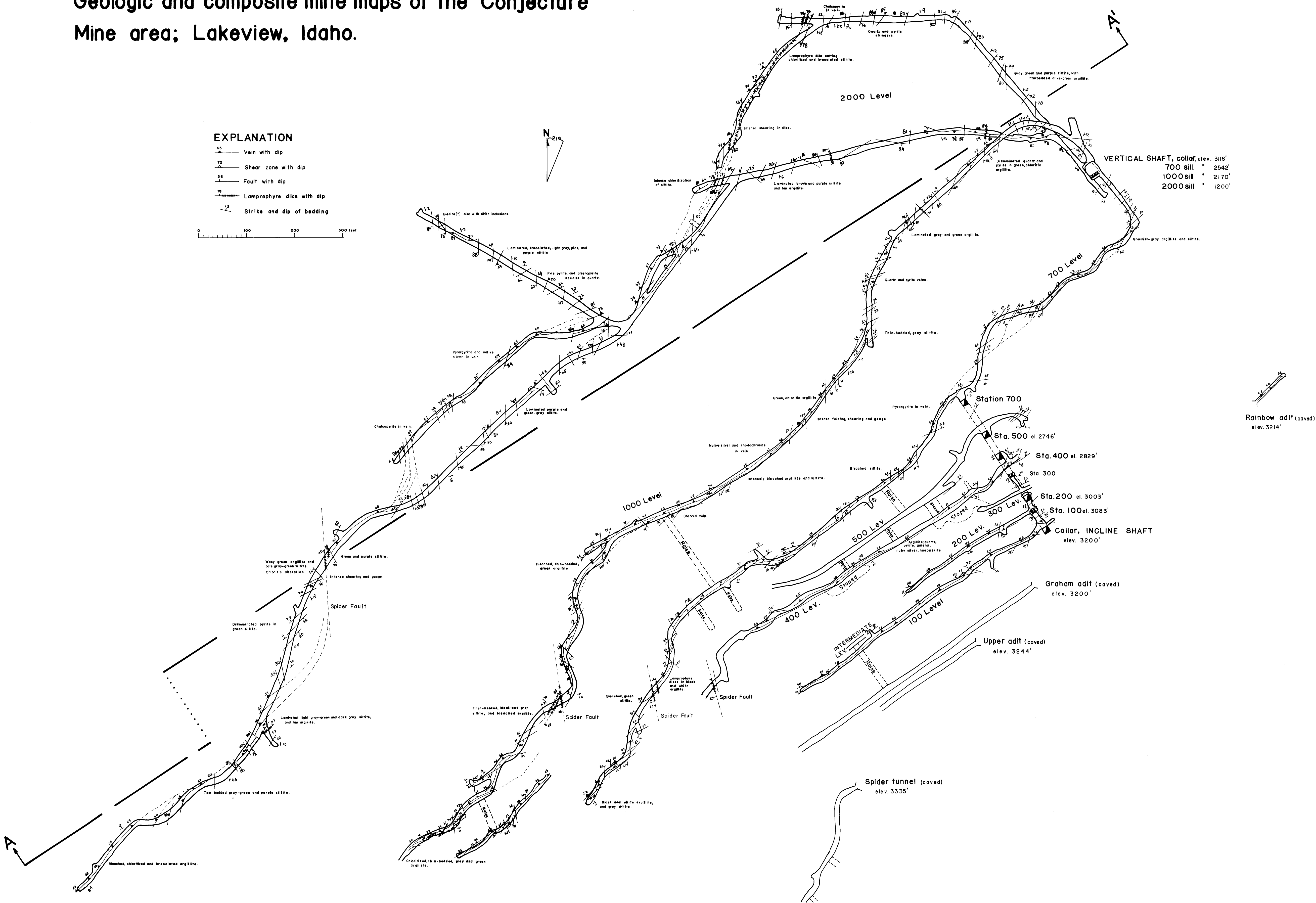


Geologic and composite mine maps of the Conjecture Mine area; Lakeview, Idaho.

EXPLANATION

- 65 — Vein with dip
- 72 — Shear zone with dip
- 56 — Fault with dip
- 78 — Lamprophyre dike with dip
- 13 — Strike and dip of bedding

0 100 200 300 feet

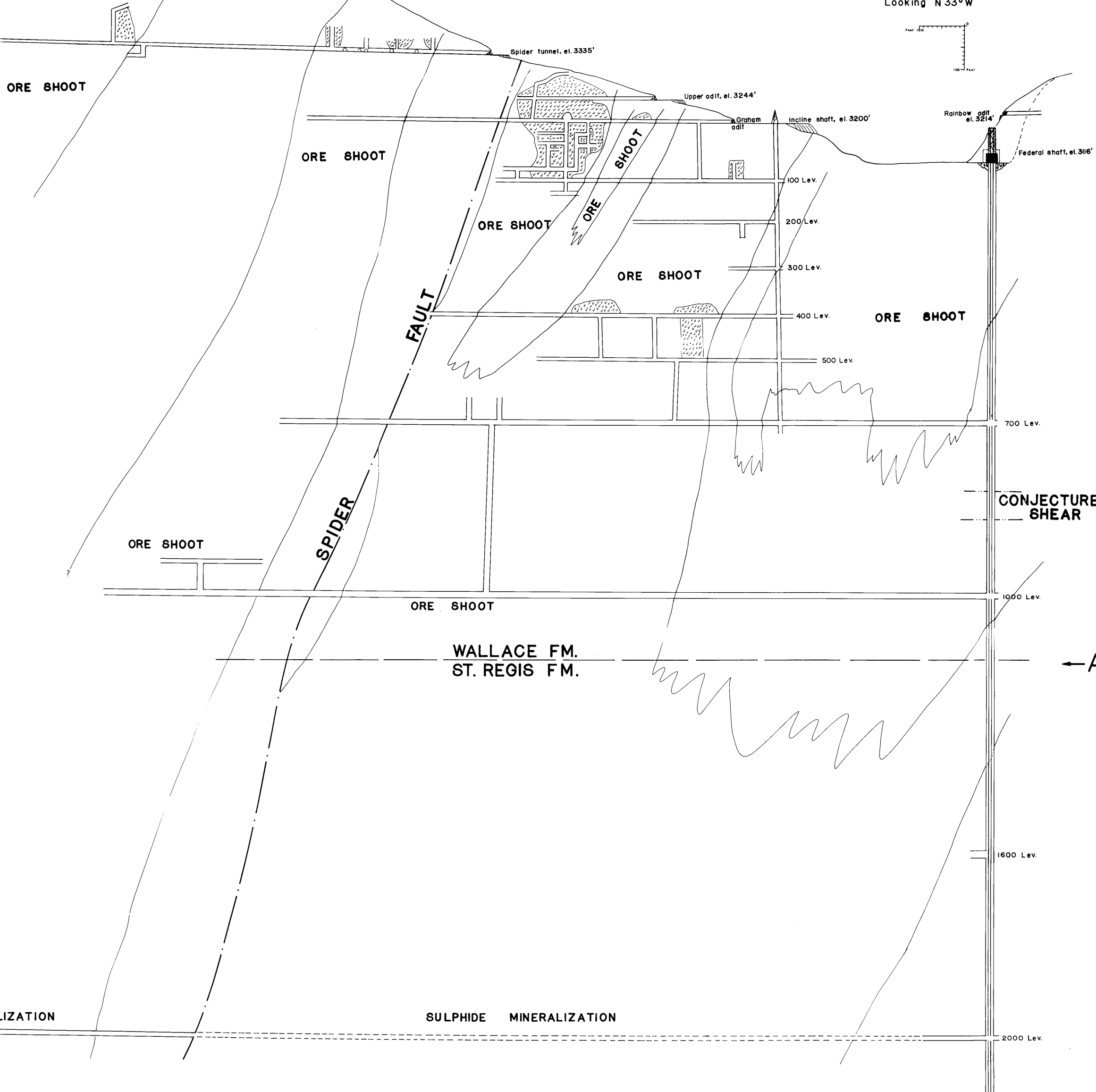
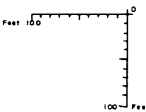


Section A-A', Conjecture Mine area.

EXPLANATION

- Stope
- Caved portal

Looking N 33° W



Geologic, composite mine, and cross-section maps of the open pit,
Nos. 2, 2½, 3 and 4 adits, Weber mine, Lakeview
mining district.

